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APPENDIX M: USE OF PROPOSED MATERIAL ON THE NATIONAL IGNITION FACILITY

M.1 INTRODUCTION

The U.S. Department of Energy's (DOE's) National Nuclear Security Administration (NNSA) is building the 192-beam National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory (LLNL). The primary goals of the NIF are to achieve fusion ignition in the laboratory and to conduct high-energy density experiments in support of national security and civilian applications. The NIF will provide NNSA with the ability to evaluate weapon performance issues to ensure that the Nation's nuclear deterrent remains safe and reliable without underground nuclear testing.

M.1.1 History

The impacts associated with construction and operation of the NIF were evaluated in the Stockpile Stewardship and Management (SSM) Programmatic Environmental Impact Statement (PEIS) (DOE/EIS-0236) (DOE 1996b). A project-specific analysis of the NIF was included in the SSM PEIS as an appendix. The SSM PEIS Record of Decision (61 FR 68014), published in the *Federal Register* (FR) on December 26, 1996, documented the decision to construct and operate the NIF at LLNL. In May 1997, the Natural Resources Defense Council (NRDC) and 39 other organizations brought suit against DOE in *NRDC v. Pena,* Civ. No. 97-936 (SS) (D.D.C.), challenging the adequacy of the SSM PEIS. In January 1998, the plaintiffs amended their complaint and alleged that the potential environmental impacts of experiments using certain hazardous and radioactive materials on the NIF were not adequately analyzed in the SSM PEIS. As a result, DOE filed the *Supplement Analysis for Use of Hazardous Materials in NIF Experiments* (DOE/EIS-SA0236-SA2) (DOE 1998c) with the court, which addressed the use of plutonium and other hazardous materials. The supplement analysis provided the basis for approval of the use of depleted uranium on the NIF and indicated that there was no new information to warrant the preparation of a supplemental SSM PEIS.

On August 19, 1998, the judge in the lawsuit issued a Memorandum Opinion and Order (USDCDC 1998) that dismissed the plaintiff's case. The Memorandum Opinion and Order provided in Paragraph 6 that:

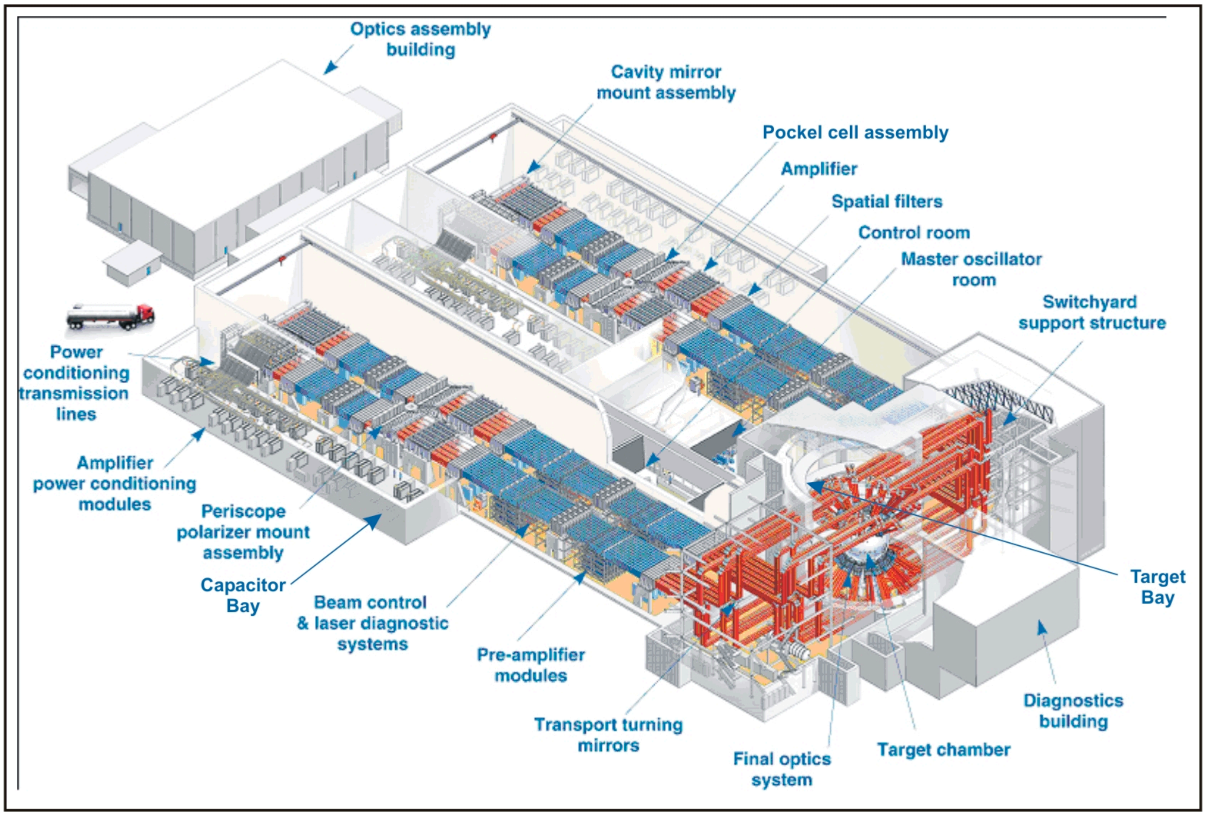
> No later than January 1, 2004, DOE shall (1) determine whether any or all experiments using plutonium, other fissile materials, fissionable materials other than depleted uranium (as discussed in the *Supplement Analysis for the Use of Hazardous Materials in NIF Experiments*, A.R. doc. VII.A-12), lithium hydride, or a Neutron Multiplying Assembly (NEUMA), such as that described in the document entitled *Nuclear Weapons Effects Test Facilitization of the National Ignition Facility* (A.R. doc VII.A-4) shall be conducted in the NIF; or (2) prepare a Supplemental SSM PEIS, in accordance with DOE *National Environmental Policy Act* (NEPA) regulation 10 CFR §1021.314 analyzing the reasonably foreseeable environmental impact of such experiments. If DOE undertakes the action described in subpart (2) of this paragraph, DOE shall complete and issue the Supplemental SSM PEIS and the Record of Decision based thereon within eighteen (18) months after issuing a notice of intent to prepare the Supplemental SSM PEIS.

NNSA has chosen to use the *Site-wide Environmental Impact Statement for Continued Operation of Lawrence Livermore National Laboratory and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (LLNL SW/SPEIS) as the mechanism for complying with the court's instruction to prepare a supplemental SSM PEIS. The inclusion of this supplemental SSM PEIS in the LLNL SW/SPEIS ensures timely analysis of these proposed experiments within the environmental impacts being evaluated for the continued operation of LLNL. The basis for the analyses in this document was a letter from NNSA (DOE 2001e) to the LLNL Associate Director for NIF Programs requesting that a consolidated technical recommendation be developed by the three NNSA weapons laboratories regarding possible experiments on the NIF using any of the materials indicated in Paragraph 6 of the Memorandum Opinion and Order. The requested tri-weapons laboratory recommendation (LLNL/NIF 2002a) represents the combined input of the Weapons Associate Directors at LLNL, Los Alamos National Laboratory, and Sandia National Laboratories. A classified annex containing the classified details of the proposed experiments was also provided by the Associate Directors (LLNL/NIF 2002b). NNSA evaluated the recommendation and the NNSA Deputy Administrator for Defense Programs determined that NNSA would propose to conduct experiments on the NIF using plutonium, other fissile materials, fissionable materials, and lithium hydride (Crandall 2002). There is no NNSA proposal regarding the use of a Neutron Multiplying Assembly on the NIF.

M.1.2 Project Description

The construction of the NIF conventional facilities is complete and installation of the laser, diagnostic equipment, and target area equipment is in progress. Laser driven experiments will be conducted in the NIF Laser and Target Area Building, the main building of the NIF. The Laser and Target Area Building consists of two laser bays, two optical switchyards, a target chamber in a shielded target bay, target diagnostics areas, four capacitor bays, mechanical equipment areas, control rooms, and operational support areas (see Figure M.1.2–1).

Housed in the Laser and Target Area Building is a 192-beam, neodymium glass laser, which delivers laser light of the required frequency and energy to small targets that are mounted in a 10-meter diameter aluminum alloy vacuum chamber. The target area provides all systems necessary to support the experiments: target chamber, target emplacement, target diagnostic inserters, support structures, environmental protection systems, and support systems. The target chamber confines the radiation and debris generated by each experiment and borated concrete shielding on the chamber surface and in the target bay attenuates neutron and secondary radiation to acceptable levels during fusion ignition experiments that produce measurable neutron yield (yield experiments) and further prevents unacceptable levels of induced radioactivity. At the center of the chamber is a target, precisely located by the target emplacement and positioning/alignment system. An integrated computer control system will control the laser and collect data from laser diagnostic equipment. These systems are supported by electrical power conditioning, diagnostic computer control systems, utilities, and mechanical and auxiliary support systems. Environmental protection systems have been designed to meet key functional requirements, such as limiting tritium inventory and tritium release to the environment. These systems are located adjacent to the target bay and consist of tritium processing systems (which recover tritium onto dryer beds for later disposal or recycling), cleaning and decontamination systems, radiation and tritium monitoring systems, and waste packaging and characterization facilities.

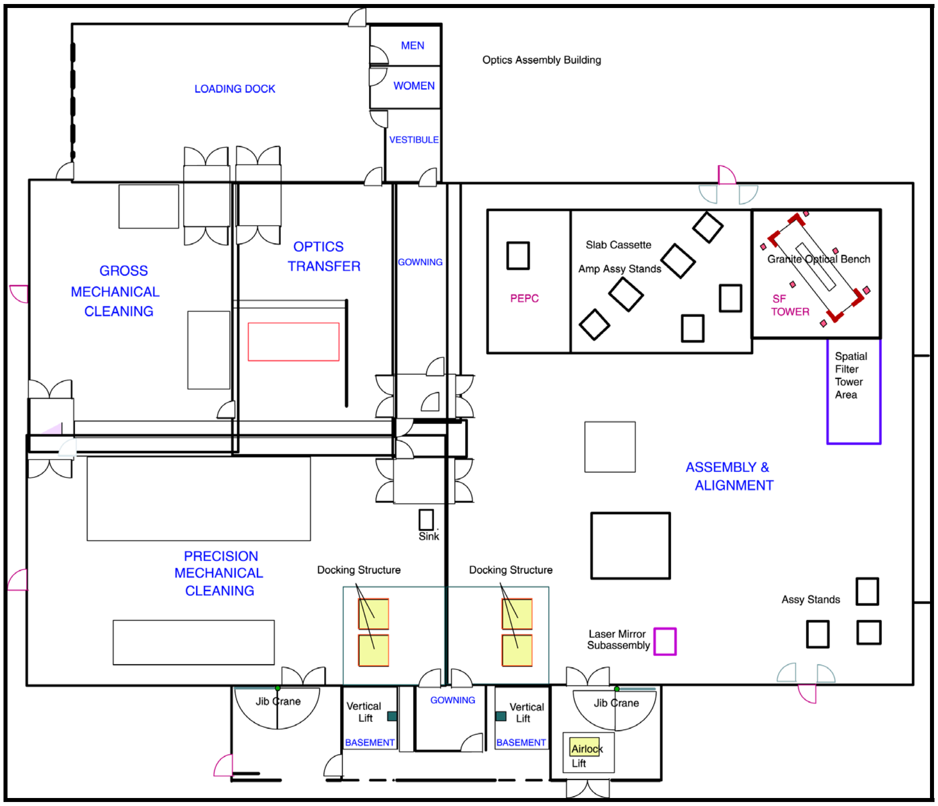


Source: LLNL File Photo 40-00-0996-2100A.

FIGURE M.1.2–1.—*National Ignition Facility Laser and Target Area Building Layout*

The Optics Assembly Building, located adjacent to the Laser and Target Area Building, includes optics processing equipment and general cleaning and precision cleaning equipment. Cleaned specialty optical components are assembled into their frames in the Optics Assembly Building (Figure M.1.2–2). These line-replaceable units are then placed into canisters for transport and insertion into the laser system.

Other required support facilities, such as assembly areas; maintenance areas; optical, electrical, machine, and mechanical shops; and offices are located nearby. In addition, the inertial confinement fusion research and development laboratories and LLNL institutional facilities such as target fabrication, waste management, central plant, development support laboratories, optics processing, and transporters are located nearby.

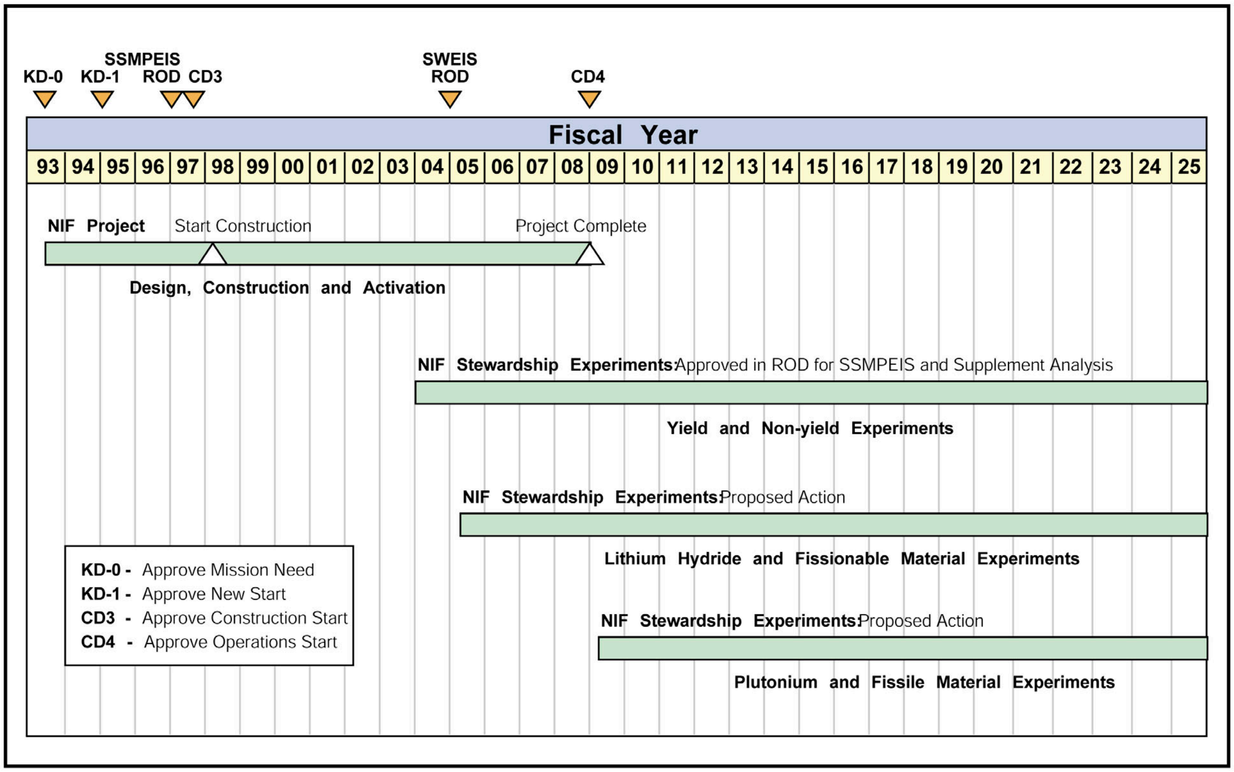


Source: LLNL File Photo LLNL/NIF-1103-07481.

FIGURE M.1.2–2.—*National Ignition Facility Optics Assembly Building Layout*

M.1.3 National Ignition Facility Operations

Experiments on the NIF for stockpile stewardship will begin in parallel with the installation and commissioning of the 192 beam lines. Figure M.1.3–1 provides a timeline for equipment installation and shows the approximate schedule for target physics experiments through 2020. The first phase of testing will include using asymmetric arrangements of the NIF laser beams and will not require the use of tritium or result in neutron yield. As symmetric arrangements of laser beams become available (approximately one half or 96 laser beams), pre-ignition experiments will begin to assess issues of beam pointing stability, power balance, and timing. Limited amounts of tritium will be used and modest neutron yields will be produced in these types of experiments. Once fully operational with 192 beam lines, the NIF will provide the capability to perform the full range of target physics experiments leading up to and including ignition and burn with energy gain. The NIF will also allow researchers to field experiments studying weapons physics, weapons effects, inertial fusion energy, and basic science.



Source: Original.
Note: See page 20 for a discussion of the terms fissile and fissionable

FIGURE M.1.3–1.—*National Ignition Facility Timeline and Relation to Use of Certain Proposed Materials*

M.1.4 Purpose of this Appendix

This appendix updates the environmental impacts of future operation of the NIF discussed in the NIF project specific analysis portion of the SSM PEIS. In addition, this appendix evaluates the proposed use of plutonium, other fissile and fissionable materials, and lithium hydride and the construction and operation of a neutron measurement device called the neutron spectrometer. Analysis of the proposal to use fissile and fissionable material and a neutron spectrometer will be based on conceptual design information, because NNSA does not have detailed designs for these experiments or the diagnostic instruments. However, sufficient information is available to analyze the reasonably foreseeable environmental impacts of these experiments and the neutron spectrometer. The analysis provided in this appendix will bound the operations of the NIF.

This appendix describes the NIF and its purpose and need as well as the purpose and need for the use of proposed materials; considers the No Action Alternative, Proposed Action, and Reduced Operation Alternative; assesses potential environmental impacts; and addresses mitigation measures.

NNSA has chosen to use the LLNL SW/SPEIS as the mechanism for complying with the court instruction to prepare a supplemental SSM PEIS. The inclusion of this appendix in the LLNL SW/SPEIS ensures timely analysis of the proposed experiments within the environmental impacts being evaluated for continued operation of LLNL. In the Record of Decision, NNSA will address decisions on the use of any or all of these proposed materials for NIF experiments within the context of continuing LLNL operations.

M.2 PURPOSE AND NEED

M.2.1 National Ignition Facility Purpose and Need

In January 1993, the Secretary of Energy approved the justification of mission need for the NIF as a part of approval of Key Decision 0 (DOE 1993a). Figure M.1.3–1 shows the timeline for approval of the key decisions for NIF. The justification stated that the NIF was being proposed to support the inertial confinement fusion program requirement to achieve ignition and propagation of thermonuclear fusion and burn. In October 1994, the Secretary of Energy approved Key Decision 1 that verified the mission need for the NIF (Reis 1994). The mission areas identified in Key Decision 1 were nuclear weapons physics, inertial fusion energy science and technology, and other applications. The nuclear weapons physics discussion stated that "In the absence of underground testing, the NIF would be a critical tool for the Department's Science-Based Stockpile Stewardship Program."

In 1996, DOE changed terminology from "Key Decision" to "Critical Decision."[1] As indicated in the footnote, the terminology went from Key Decision 1 to Critical Decision 3.

In February 1997, the Secretary of Energy approved Critical Decision 3 (Reis 1997), which affirmed the need for the NIF and stated that "The National Ignition Facility is a key element of Defense Programs' science-based Stockpile Stewardship and Management Program." In September 2000, the Secretary of Energy certified to Congress that: "The National Ignition Facility supports the Stockpile Stewardship Program (SSP), and is a vital element of it in three important ways: (1) the experimental study of issues of stockpile aging or refurbishment; (2) weapons science and code development; and (3) attracting and training the exceptional scientific talent required to sustain the program over the long term" (Richardson 2000).

In 2001, former DOE/NNSA Administrator, General John A. Gordon, certified to Congress (Gordon 2001) the importance of the NIF to the SSP based, in part, on NNSA High-Energy-Density Physics (HEDP) Report (DOE 2001h). This report concluded that:

- "A vital HEDP Program is an essential component of the SSP. The baseline HEDP Program, including the 192-beam NIF meets the SSP requirements."
- "Ignition is an important goal for the HEDP Program, the SSP and the national scientific community."
- "A laboratory ignition source is the only known means available to examine thermonuclear burn in the laboratory."
- "The intent is to produce thermonuclear burn that, for a few trillionths of a second, produces some of the conditions found only in the center of stars and in the core of an exploding

[1] The correlations between Key Decisions and Critical Decisions are: Key Decision 0 (approval of mission need) = Critical Decision 0 (approval of mission need); Key Decision 1 (approval to start design) = Critical Decision 1 (approval of preliminary baseline range); Key Decision 2 (approval to start final design) = Critical Decision 2 (approval of performance baseline): Key Decision 3 (approval to start construction) = Critical Decision 3 (approval to start construction); and Key Decision 4 (project completion) = Critical Decision 4 (approval to start operation and project closeout) .

nuclear weapon. Achieving this ignition outside of a nuclear device will be a landmark achievement for the SSP."

As indicated above, the NIF provides a unique capability for DOE/NNSA's science-based stewardship of the nuclear weapons stockpile. Planned experiments on the NIF, at temperatures and pressures approaching those that occur in nuclear weapon detonations, will provide scientific data needed to verify certain aspects of sophisticated computer models. These computer models are needed to simulate weapons performance and to provide insights on the reliability and performance of the Nation's nuclear weapons stockpile. Specially designed experiments on the NIF will address issues of modeling or physics that are of concern because of changes in weapons due to aging or remanufacture. They will also provide a unique source of radiation for studies of nuclear weapon effects; i.e., the effects of radiation on nuclear explosive package, control systems and electronics. The NIF will attract and challenge top scientific and engineering talent to address the elements of physical understanding as those necessary for stewardship of the nuclear stockpile.

It is important to have the NIF provide experimental data well before the end of the decade, as weapons continue to age beyond their original design lifetime. The NIF experiments will address, to various degrees, certain weapons issues connected with fusion ignition and boosting; weapon effects; radiation transport; and secondary implosion, ignition, and output. Most of these processes occur at very high energy density; i.e., at high temperatures and pressures, and are relevant to a weapon's reliability and performance. These experiments and thermonuclear burn are fundamental to the operation of our modern nuclear weapons stockpile.

As a multipurpose facility, the NIF also is important to the Nation's energy and basic science missions. The NIF data could indicate whether inertial confinement fusion can be a viable source of electric power in the future. Achieving ignition, optimizing target performance, and providing initial data on fusion reactor materials could allow sound decisions to be made concerning development of an inertial fusion energy demonstration facility.

NIF experiments will achieve temperatures and pressures that exist in the sun and other stars, providing new laboratory capabilities for exploring basic high-energy-density sciences such as astrophysics and plasma physics (NAS 2003a, NAS 2003b).

M.2.2 Physical Processes of Nuclear Weapons

As indicated in Section M.2.1, planned experiments on the NIF will be conducted at temperatures and pressures approaching those that occur in nuclear weapon detonations and will provide scientific data needed to verify certain aspects of sophisticated computer models. The following unclassified summary of the operation of a nuclear weapon should facilitate understanding of the need for the NIF in relation to the SSP in general.

The relevant physical processes that occur in nuclear weapons or in the immediate environment of an ongoing nuclear explosion can be divided into the following processes:

1. Detonation of high explosive and implosion of fissile materials
2. Conditions for criticality of fissile material
3. Fusion ignition and boosting
4. Radiation transport

5. Secondary implosion
6. Secondary ignition, burn, and output
7. Nuclear weapon effects on other systems

Modern thermonuclear weapons consist of two stages: a primary stage, fission trigger, and a secondary stage, fusion. The primary stage contains a subcritical "pit" of fissile material, generally plutonium, surrounded by a layer of chemical high explosives. The high explosive is detonated, burns rapidly, and compresses the pit. To increase efficiency, modern weapon primaries can employ a process called boosting. In boosted primaries, the pit contains the hydrogen isotopes deuterium and tritium.

The purpose of the primary stage is to produce enough energy in the form of radiation to implode the secondary stage resulting in thermonuclear ignition and burn. The secondary stage produces high yield for modern U.S. strategic weapons. The terms ignition and burn will be used to indicate the process in which fusion fuel is ignited and undergoes self-sustaining fusion and burn.

M.2.3 National Ignition Facility Experimental Capabilities

Specific experiments can be conducted on the NIF with weapon materials to measure relevant equations of state, such as what pressures are created at high temperatures; opacity, i.e., how a material absorbs and emits radiation; and hydrodynamics, i.e., how a material moves in response to forces applied. These experiments apply to several of the processes of interest listed in Section M.2.2. The following discussion focuses on how the NIF will be used to evaluate weapons concerns relevant to the physical processes in that list.

Experiments will be conducted on the NIF to examine the growth and control of hydrodynamic instabilities, which are important both in making inertial confinement fusion targets ignite and burn and in making nuclear weapons perform reliably. Hydrodynamic instabilities ultimately lead to mixing of some quantity of one material with another.

High temperature transport of radiation in complex geometries and materials can be examined to test the ability of computer models to predict this transport. Deposition and re-emission of radiation and the general transport problem within weapons constitute a complex process. This process must be understood to predict the transport of radiation necessary to ignite inertial confinement fusion targets.

Output calculations must be done on the inertial confinement fusion ignition targets so that the performance of the target can be properly measured. Again, however, specific targets can be designed to alter the output radiation. These experiments can be used to test the computer codes used to calculate the output of weapons.

NIF targets, either the basic type for ignition or specially designed ones, would produce x-rays, neutrons, gamma rays, and other radiation. These emissions can be used to assess the consequences of nuclear effects in electronic systems or other hardware intentionally exposed to these radiations. The survivability of military hardware subjected to various nuclear effects is an important factor in ensuring reliability of that hardware.

Experiments conducted on the NIF would address, to some degree, weapons processes that occur in Processes 3 through 7. If the stockpile surveillance program reveals an unanticipated change due to aging or remanufacture, a weapons expert can estimate which of the weapons physics processes discussed here could be affected. If any of the high-energy-density processes could be affected, then a NIF experiment could be designed to measure the physical properties of the change.

The nuclear weapons expected to remain in the stockpile will age beyond their original design lifetime between the years 2005 and 2010. Should problems arise, it is important to have the NIF in place and producing experimental results successfully during this period so that the facility can be used to help verify new computer models.

M.2.4 Purpose and Need for the Use of Proposed Materials in the National Ignition Facility

M.2.4.1 *High-Energy-Density Physics Program Needs*

The High-Energy-Density Study Report (DOE 2001h) recommended that the possibility of using special nuclear materials, defined as enriched uranium and plutonium, in experiments on the NIF should be examined. This appendix evaluates the safety and environmental effects of the use of these materials in experiments on the NIF.

In the absence of underground nuclear testing, the SSP must continually surveil, maintain, and refurbish weapons in order to certify their safety, performance, and reliability. This is done based on the ability of scientists to evaluate problems using scientific calculations that have been validated with experimental data from the NIF and other SSP facilities and using archival nuclear weapons test data.

The approach to certification by the weapons laboratories involves two major steps. The first is to identify all significant potential failure modes by using scientific and engineering judgment, results from past nuclear tests, aboveground tests and experiments, surveillance, and advanced computational simulations. Second, scientists and engineers attempt to quantify the margin and associated uncertainty, to the extent possible, for each potential failure mode. Certification is achieved by demonstrating that the margin in performance is greater than the uncertainty in the performance prediction of each potential failure mode of the device.

There are many unanswered questions regarding fundamental physical data on special nuclear materials that must still be resolved. This is because past experiments, including nuclear tests, did not examine the behavior of materials, either under the extreme conditions associated with nuclear weapons explosions or with the necessary level of precision to resolve certain fundamental physical properties of nuclear weapons materials. The SSP now demands that validated precision physical data on weapons materials be provided in computer models of nuclear weapons performance, which will allow NNSA to assess the effects of aging, engineering modifications, and safety enhancements on the stockpile. These validated models will allow continued certification of the safety, reliability, and performance of the stockpile without nuclear testing.

The NIF provides a controlled laboratory environment that makes precision and repeatable experiments possible in a way that was not available in underground nuclear testing. Both Los Alamos National Laboratory and LLNL have expressed interest in performing non-ignition and ignition experiments on the NIF using special nuclear materials. Non-ignition experiments are being developed to explore the material properties of various forms of plutonium as it is subjected to dynamic pressure and temperature environments when shocked by high-velocity flyer plates or by x-rays produced by the energetic laser beams on the NIF. Detailed information on a material's strength and equation of state can be measured on the NIF at much higher pressures than available on current or planned facilities.

When fusion ignition is achieved on the NIF, an ignition capsule would provide a unique source of x-rays and neutrons that is not available on any other current or planned aboveground experimental facility. The fusion output from an ignition capsule can be used to study nuclear, chemical, and thermomechanical behavior of special nuclear materials, including highly enriched uranium, to provide important data for weapons scientists to use in complex three-dimensional computer models of weapons behavior.

There is a need for a variety of experiments using fissionable and fissile material on the NIF as described in the following paragraphs. Additional details on these experiments are provided in the classified annex (LLNL/NIF 2002b).

- There is a need to perform experiments on the NIF with plutonium or enriched uranium without ignition. These experiments are generally designed to study the equation of state of these materials under conditions where phase changes of the material are expected to occur and to study the effects of aging on the physical properties of these materials. There is also a need for experiments to measure fundamental nuclear physics properties using plutonium or highly enriched uranium that require ignition.
- There is a need to perform experiments on the NIF with lithium hydride, which is not a special nuclear material, with and without ignition. These are materials physics and equation of state experiments designed to address fundamental physical behavior of this material and to allow benchmarking of physical models of the material.
- There is a need to perform experiments on the NIF with depleted uranium with ignition. These experiments require high atomic number materials collocated on the ignition target to enhance the conversion of laser light to x-rays for inertial confinement fusion experiments. There is also a need for experiments that use depleted uranium or highly enriched uranium with ignition to study the physics of these materials.
- There is a need to perform experiments on the NIF with fissionable materials (i.e., thorium-232, and fissile materials; e.g., highly enriched uranium,) with ignition. These experiments require the materials to be collocated on the ignition target to provide a measurement of the nuclear processes that occur in an ignition capsule.

There is no NNSA proposal for using a neutron multiplying assembly for experiments on the NIF (Crandall 2002).

The use of special nuclear material on the NIF will allow weapons scientists to accurately evaluate the properties of special nuclear material in the laboratory and to validate weapons test data and refine computer codes to lower the margin of error for these calculations.

M.3 DESCRIPTION OF THE NO ACTION ALTERNATIVE, PROPOSED ACTION, AND REDUCED OPERATION ALTERNATIVE

The construction of the NIF conventional facilities is complete and installation of the laser, diagnostic equipment, and target area equipment is in progress. Experiments on the NIF for stockpile stewardship will begin in parallel with the completion of installation and commissioning of the 192 beam lines. The NIF will transition into full operation following the approval of Critical Decision 4, scheduled to occur in 2008. NEPA compliance for conventional facility construction and equipment installation of the NIF is described in the NIF project-specific analysis of the SSM PEIS (DOE 1996b) and was amended by the Supplement Analysis for the use of Hazardous Materials in the NIF Experiments (DOE 1998c) and the Supplemental SSM PEIS (DOE 2001f).

This appendix analyzes the No Action Alternative, Proposed Action, and Reduced Operation Alternative for the NIF. Section M.3 is broken into subsections as follows:

- M.3.1 covers the No Action Alternative, which includes the NIF experiments and operations for which decisions have already been made and provides information on the hazardous and radioactive materials approved for use on the NIF.
- M.3.2 covers the Proposed Action for changes in NIF operations; the use of plutonium, other fissile materials, fissionable materials, and lithium hydride in experiments on the NIF; and the construction and operation of a neutron spectrometer.
- M.3.3 evaluates the Reduced Operation Alternative for the NIF.
- M.3.4 provides a summary and comparison of the environmental impacts of the No Action Alternative, Proposed Alternative and Reduced Operation Alternative.

Table M.3–1 summarizes the differences in the operating parameters of the Proposed Action and alternatives.

The data for this appendix were taken mainly from two documents: the SSM PEIS, Volume III, Appendix I (DOE 1996b) and the *NIF Project Input for Assessment of Environmental Impacts of the NIF* (LLNL 2003d).

TABLE M.3–1.—*National Ignition Facility Operating Parameters for Each Alternative*

	No Action Alternative	Proposed Action	Reduced Operation Alternative
Laser energy	1.8 MJ, 192 beams	1.8 MJ, 192 beams	1.8 MJ, 192 beams
Yield, maximum	20 MJ[a]	20 MJ[a]	20 MJ[a]
Total	1,200 MJ/yr	1,200 MJ/yr	800 MJ/yr
Tritium,	1,750 Ci/yr	1,750 Ci/yr	1,500 Ci/yr
Throughput,	500 Ci	500 Ci	500 Ci
Inventory in process,			
Plutonium	No	Yield and nonyield experiments	No
Fissile material use	No	Yield and nonyield experiments	No
Fissionable material use	Only nonyield depleted uranium	Yield and nonyield experiments	Only nonyield depleted uranium
LiH	No	Yield and nonyield experiments	No
Neutron spectrometer	No	Yes	No
Removable inner containment vessel	No	Yes	No
Facility hazards category	Low-hazard, radiological	Low-hazard, radiological	Low-hazard, radiological

Source: LLNL 2003d.
[a]45 MJ maximum credible yield.
Ci = curie; LiH = lithium hydride; MJ = megajoules; yr = year.

M.3.1 No Action Alternative

The No Action Alternative comprises the continued installation of equipment and operation of the NIF. Under the No Action Alternative, the NIF would be operated under the parameters described in the SSM PEIS NIF project specific analysis and summarized in Table M.3–1. The NIF would perform the full ignition program required to meet SSP goals but would not perform experiments with plutonium, other fissile materials, fissionable materials (other than depleted uranium), or lithium hydride. The neutron spectrometer would not be constructed. The NIF would be operated as a low-hazard radiological facility.

This section expands on the basic information provided in Section M.1.2 and provides an overview of the experiments and operation of the NIF. Information is provided on the use of resources and materials under the No Action Alternative. The manner of operation of the NIF laser and target area building and the laser system would be the same for all of the alternatives and will not be repeated in the Proposed Action and the Reduced Operation Alternative sections. The level of operation (number of experiments) and the quantity of materials used would vary among No Action Alternative, Proposed Alternative and Reduced Operation Alternative.

The NIF consists of three main elements housed in the laser and target area building, a single environmentally controlled building. The elements of the NIF are the laser system and optical components, a target chamber placed within a target bay, and an integrated computer system to control the laser and diagnostic equipment. The following sections cover the operation and hazards associated with the NIF laser and target area building (Section M.3.1.1), the laser system (Section M.3.1.2), the target chamber and target area (Section M.3.1.3), and NIF experiments (Section M.3.1.4). Section M.3.1.5 discusses hazardous material use in NIF operations, and Section M.3.1.6 covers facility decontamination and decommissioning (D&D).

The computer control system is an integrated network of computer systems providing the hardware and software needed to support full operational activities. The system includes the computer controls to manage the laser optical system, target system, and data acquisition. Information on the computer control system is not addressed in this appendix. Certain control systems, such as the safety interlock system, are presented where pertinent to the discussion of environmental impacts and accidents.

M.3.1.1 *National Ignition Facility Operations*

The laser and target area building is a reinforced concrete and structural steel building constructed to be vibration isolated, provide radiation confinement and control, and include all necessary system control and diagnostics. It consists of two laser bays, two optical switchyards, a target chamber in a shielded target bay, target diagnostic areas, four capacitor bays, mechanical equipment areas, control rooms, and an operational support area (Figure M.1.2–1).

The laser bays are steel-framed, metal-sided rooms with a metal deck roof and steel-reinforced concrete floor. Each laser bay houses 96 individual laser beam lines. The capacitor bays are four separate rooms that house the power conditioning system used to operate the main laser amplifiers. Capacitor bay equipment includes capacitors, spark-gap electrical switches, and power conditioning equipment. The power for the NIF laser would be supplied by discharging the bank of capacitors. The capacitors would be charged using electricity supplied from LLNL utility system.

The two optical switchyards house optical systems, that is, mirrors and beam tubes, that direct and position the 192 laser beams into the target bay. The switchyards are constructed of steel-reinforced concrete.

The diagnostic building, adjacent to the target bay, houses the environmental protection systems, target receiving area, tritium processing area, and diagnostic support areas. The tritium processing system would operate by oxidizing gaseous tritium and capturing the oxidized tritiated water on molecular sieves. The tritium processing system molecular sieve canisters would be replaced periodically. The preheater reactor and metal bellows pump would be replaced infrequently (on the order of every 10 years).

Facility Utility Usage

Facility operations would require the use of electrical power, water, and natural gas, and would discharge wastewater. The NIF would use electricity to operate the laser and plant equipment necessary to support basic operations. This would include operations of the heating, ventilation, and air conditioning system (HVAC), chilled and heated water systems, lighting, facility heating, etc. The clean-room high-efficiency particulate air (HEPA) filters clean the supply air going into the building.

Water would be used at the NIF for a variety of operations, including boilers, cooling towers, domestic use, landscape irrigation, washing, and fire hydrant testing. Some of the water would be evaporated to the atmosphere, while other water would be discharged to the sanitary sewer or storm drain, as appropriate. More details concerning projected water use and discharge quantities for the NIF are provided in Section M.5.

The NIF has two standby diesel generators; one is 754 horsepower and the other is 250 horsepower. In the event of a power outage, these generators would operate until the utility power is restored.

M.3.1.2 *Laser Operations*

The NIF laser system would generate and deliver high-power optical pulses to a target suspended in the target chamber. Multiple laser beams would be used to uniformly illuminate the target surface area. The NIF laser contains 192 independent laser beams, or beamlets. Each laser bay houses twelve bundles. Each bundle is made up of two quads of four individual beamlets. Each quad has a unique beam path, or beamline, to the target chamber. The 192 beamlets require more than 10,000 discrete optical components. The laser requires all optical components to be enclosed in a controlled beam tube that is under a vacuum or filled with an inert gas (argon) or a clean gas system of an oxygen/nitrogen gas mixture. The clean gas system provides backfill gas for the amplifiers and beam transport system portions of the laser. Argon is provided to the beam transport system in the switchyard and target bay.

The operating parameters established for NIF experiments are indicated below.

- Laser power/energy to the target: 500 terrawatts/1.8 megajoules
- Maximum design yield per experiment: 20 megajoules (maximum credible yield would be 45 megajoules)
- Annual total yield: 1,200 megajoules per year

M.3.1.3 *Target Bay and Target Chamber*

Target Bay

The target bay houses the following major subsystems: target chamber, target emplacement positioner, target diagnostics, support structures, environmental protection, and vacuum and other auxiliary systems. The target bay is a steel reinforced concrete cylindrical structure that houses the target chamber. The steel reinforced concrete would provide initial shielding of radiation produced during yield experiments.

The target bay also would provide radiation confinement in conjunction with the HVAC system for radioactive air emissions, such as activated air created during high-yield experiments or a tritium release. The exhaust would discharge from an elevated release point. The exhaust air would be continually monitored to ensure detection of activated material.

Environmental protection systems, including tritium-handling systems, target storage, and decontamination equipment used to clean the target chamber components, will be located in the decontamination area adjacent to the target bay. X-ray, optical, and neutron measurement instruments would be arranged around the chamber to help evaluate the success of each target experiment. Structural support of the target diagnostics, the target positioner, final optic assemblies, and turning mirrors, would be provided by target area structures. The target area would also provide the following subsystems: the target area auxiliary systems, material handling, the target chamber boom lift, and the diagnostics and control rooms.

The NIF shielding design consists of several components. The basic components include the target chamber borated concrete shielding; target bay walls that are 1.83-meter-thick concrete; target bay roof that is 1.37-meter-thick concrete; switchyard walls that are up to 1.14-meter-thick concrete depending upon the specific location, and switchyard roofs that are 0.46-meter-thick concrete. Due to the large number of penetrations through the target bay walls, additional shielding components have been added. These include mechanical equipment room walls that are 0.31-meter-thick concrete; HVAC collimators, concrete tubes that allow airflow to pass while providing a tortuous path for neutrons and gamma-rays; and switchyard collimators 1.83-meter-long extensions of the target bay walls on the switchyard side of the walls.

Target Chamber

The NIF target chamber is a 10-meter internal-diameter spherical aluminum alloy shell with 10-centimeter thick walls. The exterior of the chamber is encased in 40 centimeters of borated concrete to provide neutron shielding. The target chamber would provide the primary confinement for target experiments. The target chamber is supported vertically by a hollow concrete pedestal and horizontally by radial joints connected to the cantilevered floors. The laser beams would enter the chamber in two conical arrays from the top and two conical arrays from the bottom. At the poles and in the equatorial regions of the chamber, diagnostic equipment would be inserted through the chamber wall. The target chamber would also include the target emplacement and positioning/alignment system.

The laser beams would enter through laser optics, e.g., glass lenses, frequency conversion crystals, and other optics, called the final optics assembly that would be attached to the end of each beam line as it enters the target chamber. The final optics assembly would be protected from damage by a main debris shield and a disposable debris shield. There would be an ongoing waste stream of solid low-level waste (LLW) from replacement of the disposable debris shields.

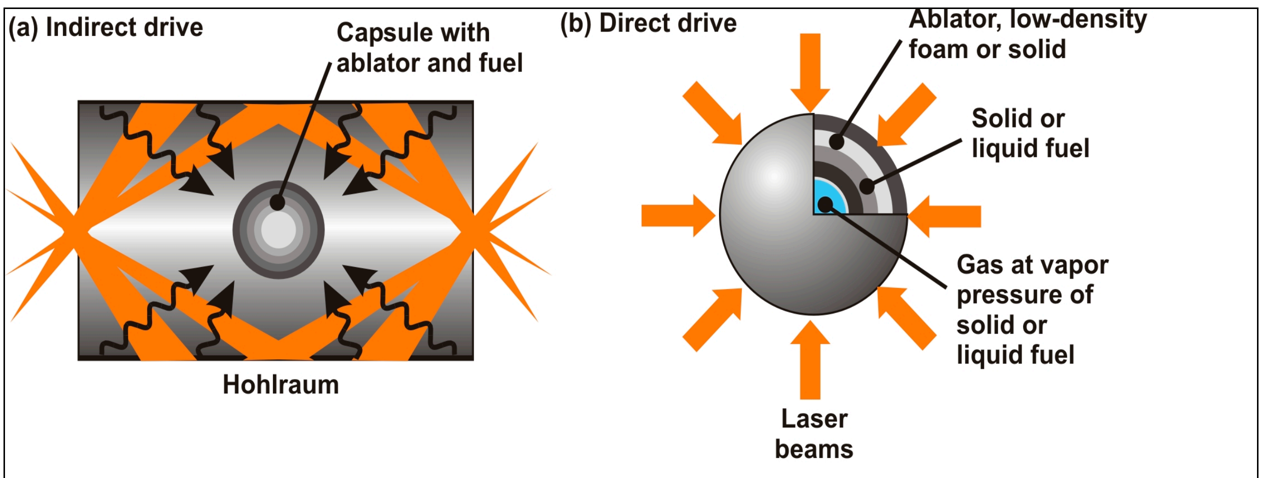
Some of the main debris shields would require periodic cleaning and could require replacement and disposal due to damage.

Laser light would leave the final optics assembly and illuminate the target at the center of the chamber. The diagnostics would capture the required data. Light that is not absorbed by the target would continue towards the opposite wall of the target chamber. Just before hitting the target chamber wall, unconverted laser light that hits the opposite wall would be absorbed by the light-absorbing stainless steel first wall panels located opposite of each beam port. The first wall panels, which would also provide protection of the target chamber from debris and soft x rays, would require periodic replacement due to wear, damage, and/or chemical contamination. It is anticipated that the panels would be replaced once every eight years, resulting in solid radioactive LLW.

The components used in target chamber diagnostics could be damaged during higher yield experiments and become a solid LLW stream. Filters would process the target chamber air exhaust. Charcoal filters would also be used to capture certain isotopes, and these would need periodic, but infrequent replacement. There will be two high-efficiency particulate air filters and two prefilters controlling the emissions from the target chamber. There would be approximately 20 additional HEPA filters with local area control applications. A change out schedule of at least once every 10 years would be required by LLNL. Filter disposal would generate solid LLW.

M.3.1.4 *National Ignition Facility Experiments*

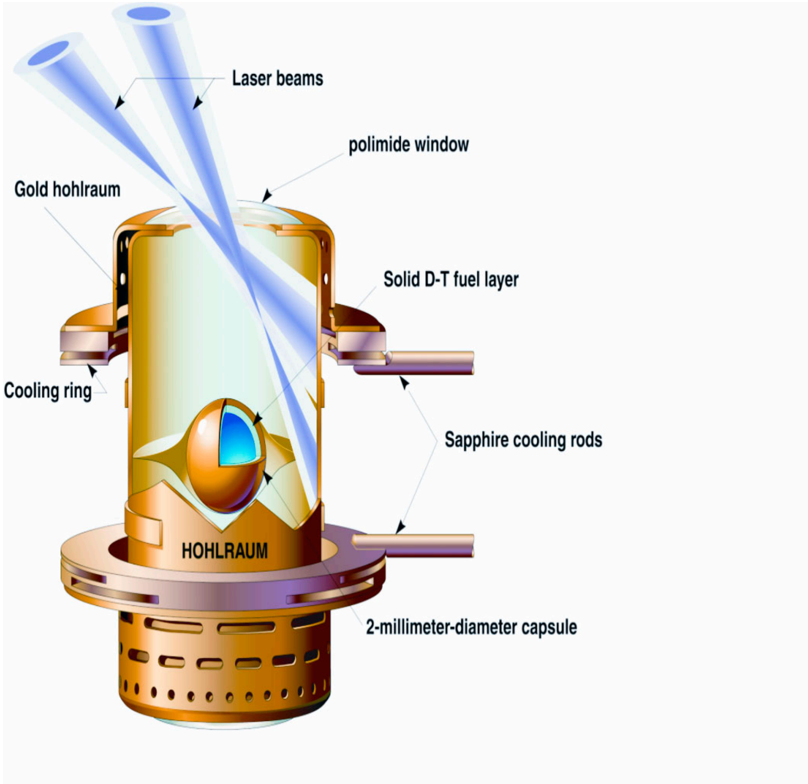
Both indirect-drive and direct-drive experiments could be conducted on the NIF, as illustrated in (Figure M.3.1.4–1). Initial operation of the NIF would use indirect-drive experiments where x-rays generated by the interaction of the laser beams with a small metal cylinder or hohlraum would cause the compression of the target (Figure M.3.1.4–2).



Ignition experiments on NIF would use indirect drive to heat the inside of a cylinder (hohlraum). The incident laser light would enter the cylinder through holes at its end caps and would be converted to X rays that would converge on a 2-millimeter-diameter capsule. NIF would also have an option to conduct direct-drive experiments, with the laser light directly incident on a capsule.

Source: LLNL File Photo LLNL/NIF 1103-07482.

FIGURE M.3.1.4–1.—*Indirect- and Direct-Drive Experiment Modes*



Source: LLNL File Photo LLNL-05-00-0798-162.

FIGURE M.3.1.4–2.— ***Schematic View of Hohlraum***

Direct-drive experiments could also be conducted on the NIF. With direct drive, the laser beam, rather than x-rays, would directly compress the target. When the laser fires on an ignition target, all 192 beams would be synchronized and simultaneously illuminate the target. The target would be compressed and heated, creating intense fusion reactions. The direct-drive mode was discussed as part of the SSM PEIS.

Indirect-drive-yield experiments using deuterium and tritium would emit neutrons, energetic particles, debris, and x-rays. The energetic particles, debris, and x-rays would be confined within the aluminum alloy target chamber. Most neutrons and secondary radiation from a yield experiment would travel through the target chamber and its surface shielding layer before being adequately attenuated by target bay structures and concrete walls. Some neutrons would activate target bay structures, including the target chamber, shielding, space frame, optics, beam tubes, catwalks, and reinforced concrete walls.

Tasks that must be performed within the target bay or that involve handling of materials that have been inside the target bay during experiments would result in some level of radiation dose. Dose rates within the target bay would be largely dependent on the yield of the most recent experiment and the amount of time since the experiment took place. The residual radiation intensity within the target bay at any particular location would depend upon local and general activation in the room as well as the history of yield experiments.

Radiation Produced from Fusion Experiments

Neutrons would also penetrate through the roof of the facility and cause skyshine radiation, where the neutrons scatter (reflect) off of the atmosphere above the facility and scatter back down to the ground. Some neutrons would interact with structural material and emit gamma rays as they undergo nuclear reactions, and these gamma rays would also reach the ground.

Tritium

Tritium would arrive at the facility in individual targets, containing up to 5 curies each; 2 curies in the capsule and up to 3 curies in the associated hardware. If direct drive is implemented, each target would contain up to 70 curies. The annual tritium throughput at the NIF would be limited to 1,750 curies per year.

The tritium in-process inventory limit for the NIF would total no more than 500 curies. Tritium could be in process in various locations at the NIF, but would remain below the 500 curies total in-process inventory limit. The total in-process tritium inventory would include any accumulation of tritium in the facility that is releasable and quantifiable, and that is part of the tritium handling cycle in the NIF. This would include inventories in locations such as targets and associated hardware, cryopumps, molecular sieve traps, and decontamination systems. It would not include residual surface contamination and adsorption. Therefore, the tritium adsorbed on the target chamber walls after an experiment would not be part of the in-process inventory.

Particulates

Particulates would be generated in the target chamber from each experiment. During an experiment, the laser energy would vaporize the target. Reflected or unused laser light is absorbed on the protective first wall panels and would induce ablation of this surface, with the loss of mass from the surface of the wall panels by vaporization or as small molten droplets. The emission of x-rays from the experiment could be sufficiently high to induce yet further ablation from nearby equipment surfaces, protective first wall panels, and debris shields. Structures close to the target could undergo melting during high yield experiments. The state of the ablated material after an experiment is expected to be small pieces of debris and fine particulates. For the purpose of this analysis, it was conservatively assumed that all the ablated material would exist as fine particulates about one micron in size; i.e., most easily made airborne and in the respirable range.

As the particulate material is exposed to neutrons from yield experiments, some material would become activated and converted to radioactive material. The particulates would accumulate in the target chamber until the scheduled annual cleanup. The total inventory of activated, mobilizable particulates created in the chamber would be quite small. A list of the prominent nuclides that would be expected as activated particulate in the chamber, room air, and in beam tubes is presented in Section M.5.

M.3.1.5 *Hazardous Materials*

Materials needed to support NIF operations would include inert gases (argon) for laser operations, nitrogen for cryopumps, and other chemicals for cleaning, decontamination, and general use. Some of these materials would be regularly consumed; others could be expended and require replacement during the lifetime of the NIF. There would be no explosives stored or used at the NIF.

The NIF would use volatile organic solvents for lens cleaning and other wipe cleaning operations in the clean room environment. These would include ethanol, acetone and isopropanol. The main agent currently used (Brulin 815 GD) contains no hazardous ingredients, according to its material safety data sheet, and is generally approved for discharge to the sewer. The usage of solvents for wipe cleaning has been greatly reduced by using dilute aqueous solvent solutions, steam cleaning, dry wiping, and other techniques. Other chemicals would be stored in small quantities at the facility. Acetone and ethanol are used only for occasional spot cleaning. Clean room wipes presaturated with 9 percent isopropanol in de-ionized water would be used more frequently, but also in small quantities.

Decontamination processes require a working inventory of cleaning agents. An onsite inventory to replenish working solutions is also needed. This includes phosphoric acid, nitric acid, and sodium hydroxide. These will be utilized in cleaning solutions in the decontamination area.

The power conditioning units used in support of the preamplifier modules would have sets of ignitron switches, which would contain mercury. Each of the 48 preamplifier modules would have a dedicated, closed ethylene glycol/deionized-demineralized water coolant loop for thermal control.

The NIF would handle small quantities of beryllium in the form of targets, up to 1.6 grams, and in diagnostic windows. The NIF would use beryllium in two forms: protected collected solids, primarily in filters, that cannot become particulate, and material in exposed diagnostics and targets that can become particulate. It is not anticipated that there would be significant airborne exposure to workers. This will be confirmed by air monitoring. Surface swiping would be performed to confirm that surface beryllium contamination remains within permissible housekeeping limits for beryllium work areas (10 CFR Part 850).

Targets and hohlraums would be made of components that could include small quantities of hazardous and toxic materials including beryllium, lead, dysprosium, gadolinium, germanium, scandium, silicon, tantalum, and titanium. During an experiment, energy, through either indirect drive with a hohlraum or direct drive, would be deposited on the target resulting in the general vaporization of the target and hohlraum. The debris from the target and hohlraum would be deposited on the target chamber wall and debris shields. Some debris could take the form of particulates (see Section M.3.1.4.3). This appendix assumes that the target chamber would only be decontaminated once per year, to conservatively bound the amount of activated particulates and worker exposure. The actual schedule for decontamination of the target chamber would be managed according to the schedule of experiments, the amount of materials in the target chamber, and the risks to decontamination workers. Decontamination of the target chamber would be performed in accordance with radioactive and hazardous material handling procedures appropriate to the content of the material in the chamber at the time of the decontamination.

M.3.1.6 *Decontamination and Decommissioning of Facilities*

A D&D plan was developed for the NIF during design of the facility (LLNL/NIF 2001). The plan outlines the D&D planning activities and describes general assumptions about the facility including components and their projected status or disposition at the facility end of life. The main purpose of the plan was not to project waste amounts, but to ensure that the decommissioning could be easily accomplished and to examine design features that could facilitate the eventual D&D of the NIF. The NIF is assumed to operate for 30 years. The D&D of the laser would involve the reuse or salvage of materials, storage of research materials for later experiments in follow-on facilities, and disposition. Most of the waste would be industrial waste.

Cleanup of the NIF target area is expected to generate a total of 263 of cubic meters of LLW waste (including the shipping containers) and 226 cubic meters of hazardous waste (LLNL/NIF 2001). Following D&D of the building, it would be returned back to the institution for further use. Useful building utilities, conventional lighting, water, etc., will remain in place. D&D of the neutron spectrometer would produce another 30 cubic meters of hazardous waste.

M.3.2 Proposed Action

The Proposed Action section discusses the additions to NIF operations that would result from the proposed use of plutonium, other fissile materials, fissionable materials, and lithium hydride in experiments on the NIF. These experiments, as well as the operation of the NIF, have a design lifetime of 30 years. For this discussion the materials considered are: fissile materials; i.e., materials that fission when irradiated by slow or thermal neutrons) such as uranium-235 or plutonium-239, and fissionable materials, i.e., materials that can be induced to fission by fast neutrons such as uranium-238 (depleted uranium) or thorium-232. The specific fissile/fissionable materials (beyond depleted uranium) considered for the Proposed Action would be weapons-grade plutonium[2], highly enriched uranium[3], and thorium-232. Yield experiments and nonyield experiments with highly enriched uranium, thorium-232, and other fissionable materials would most likely be performed in the NIF target chamber without additional containment. Plutonium experiments would be performed using an additional inner containment vessel (see Section M.3.2.1) to protect the target chamber. Experiments with small quantities of specially prepared plutonium could be used without an inner containment vessel provided the environmental impacts do not exceed the bounds defined in this document. It is estimated that there would be a maximum of four yield experiments (with plutonium) per year, at fusion yields up to 45 megajoules, and 10 nonyield plutonium experiments per year with inner containment. If other fissile materials were required for NIF experiments the inventories of these materials would be limited such that their environmental impact, such as offsite accidents, worker exposure, etc., would not exceed the bounds defined in this document. Other materials that would also be used in the Proposed Action at the NIF are beryllium, depleted uranium, and lithium hydride (including lithium deuteride[4]).

In addition, the Proposed Action would include the construction and operation of a neutron spectrometer to more accurately measure neutron yield and diagnose ignition target physics (see Section M.3.2.4).

Section M.3.2.1 discusses the proposed experiments with fissile and fissionable material and changes in the target chamber operations and related information. Section M.3.2.2 covers transportation of materials, and Section M.3.2.3 covers waste generation. Section M.3.2.4 covers the construction and operation of a neutron spectrometer.

The experiments under the Proposed Action involving the use of plutonium, other fissile materials, fissionable materials, and lithium hydride in targets would be in addition to the types

[2] The assumed composition of weapons-grade material is 0.02% plutonium-238, 93.85% plutonium-239, 5.8% plutonium-240, 0.3% plutonium-241, 0.015% americium-241, and 0.02% plutonium-242. Other isotopic mixes could be used if their impacts were within the bounds described here.

[3] Highly enriched uranium contains equal or greater than 20 % uranium-235.

[4] Lithium deuteride consists of lithium and deuterium, which is the nonradioactive isotope of hydrogen.

of experiments that would take place under the No Action Alternative. The basic operation of the facility, the laser, the target area, and eventual D&D of the NIF, would not be affected by these additional types of experiments. They would be the same as described for the No Action Alternative. Therefore, only those aspects of operations that would be changed are discussed here.

M.3.2.1 *National Ignition Facility Experiments*

Section M.2.4 discusses the purpose and need for the use of the proposed materials; i.e., plutonium, other fissile materials, fissionable materials, and lithium hydride in NIF experiments. This section describes the types of experiments that would be conducted and the types of materials that would be used in these experiments. The experiments that are being considered include yield experiments and nonyield experiments using any of the proposed materials. These would be bounded by the yield and nonyield experiments with plutonium.

Experiments with depleted uranium, highly enriched uranium, lithium hydride, fissionable materials, fissile uranium, and experiments with small quantities of specially prepared plutonium would occur in the target chamber in the same manner as all other experiments discussed under the No Action Alternative. There would be both yield and nonyield experiments with these materials. Yield experiments with highly enriched uranium and fissionable materials would generate fission products, but negligible plutonium quantities. These materials would use the same target positioner and similar diagnostics. No new features would have to be added to the NIF or the support facilities to field experiments with these materials. The NIF would be operated as a low-hazard radiological facility under the Proposed Action.

Experiments with Plutonium

For this analysis, a tritium fusion yield experiment with plutonium is covered as the bounding condition. As indicated above, experiments with small quantities of specially prepared plutonium could be conducted without an inner containment vessel. These experiments would be bounded by those covered under the Proposed Action. These experiments would, in general, create additional radiological concerns because fission products would be generated and neutron activation of materials could occur. Because most isotopes of plutonium have a much higher activity than highly enriched uranium, depleted uranium, or thorium-232, a separate inner containment vessel fabricated from stainless steel would be used to prevent the plutonium and fission products from being deposited on the target chamber, first wall, target positioner, or diagnostics. This inner containment vessel would be assembled at a LLNL support facility and transported to a LLNL facility such as the Tritium Facility for loading. Just prior to a plutonium experiment with inner containment, the target would be inserted into the inner containment vessel and the inner containment vessel would be transported in a shipping container to the NIF as a sealed and assembled unit. The inner containment vessel would be placed into the NIF target chamber through the large port on the target chamber equator or through the bottom of the target chamber.

Seismic requirements for support of the inner containment vessel would require new "hard points" being installed in the target chamber to support the inner containment vessel. The side entry system through the large port on the equator would require a custom built manipulator and installation of tracks from the diagnostics building into the target bay. The tracks would have to be removable to close the shield door for yield experiments. Other systems, such as lifting devices, cryogenic systems, and the liquid helium transfer system, could require modification.

Following the installation of the inner containment vessel and the diagnostic package, the target chamber would be evacuated and the laser fired on target. Deposition of laser energy on the target would result in vaporization of the target, emission of x-rays, the release of neutrons and the fission of the plutonium atoms for yield experiments. Radioactive materials generated from these experiments would include plutonium from the vaporized target, activated particulates from neutron activation, and fission products from the fission of the plutonium used in the experiment. All of these materials would be contained by the inner containment vessel. Additionally, x-rays and unconverted laser light would ablate material from surfaces and components, creating particulates in the inner containment vessel.

Once the experiment is completed and after a suitable waiting period, the inner containment vessel would be removed from the NIF target chamber and returned to a LLNL facility, such as the Tritium Facility, for post-experiment examination, processing, and, if needed, decontamination. Personnel at the NIF would not be exposed to the materials inside the inner containment vessel. The inner containment vessel, having been used in a single experiment, would then be placed in a shipping container, either dismantled or whole, and transported to the Nevada Test Site for disposal as LLW. Because the inner containment vessel would only be used for a single plutonium experiment and then removed from the NIF, the bounding inventories for the yield experiment case would include 1 gram of weapons-grade plutonium and the associated fission products and activated particulate. For nonyield experiments, the bounding inventory would be 3 grams of weapons-grade plutonium.

Modifications to LLNL Tritium Facility to accept the inner containment vessel would include adding hoisting and rigging equipment to place the inner containment vessel into a special glovebox. This glovebox would be used to retrieve samples from the inner containment vessel and decontaminate and dismantle, as necessary, prior to shipment to the Nevada Test Site.

Personnel Exposure

For most yield and nonyield experiments with plutonium, placement of the inner containment vessel into the NIF target chamber and its removal after the experiment would result in worker exposure from the target chamber. During this time, personnel are assumed to be in close proximity to a large, open target chamber port. Because they would have a line-of-sight view to the activated target chamber interior, activated as a result of previous experiment, and the inner containment vessel, they would receive some additional amount of exposure. The exposure would be greater during removal of the inner containment vessel after yield experiments because both the inner containment vessel and the NIF target chamber would be further activated from neutrons released during the experiment.

Post-experiment activities would most likely be conducted at the LLNL Tritium Facility and appropriate protective measures, such as protective clothing and gloveboxes, would be used to prevent plutonium exposure would be used. The post-experiment activities that would be conducted in the Tritium Facility include installation of the inner containment vessel into a large glovebox, access to the interior of the inner containment vessel to retrieve samples, if needed, and decontamination and dismantlement of the inner containment vessel prior to shipment as waste. Worker dose would occur mostly due to exposure to the activated inner containment vessel. The inner containment vessel would become activated only for yield experiments.

The increased dose for the Proposed Action would be largely the result of yield experiments, and would occur during removal of the inner containment vessel and post-experiment processing.

Smaller doses are incurred for nonyield experiments (during inner containment vessel placement and removal), and during placement of the inner containment vessel for yield experiments. This additional dose (beyond that of the No Action Alternative) was estimated assuming 4 yield experiments with plutonium at 45 megajoules each and 10 plutonium nonyield experiments per year.

Experiments Without Inner Containment Vessel

Radioactive material generated during these experiments would include neutron-activated radioactive particulates created in the target chamber and any fission products generated during yield experiments with plutonium, highly enriched uranium, depleted uranium, or thorium-232. These radioactive materials would be transferred to the decontamination systems and waste streams as a result of decontamination of the target chamber components. However, because many of the isotopes have short half-lives, the maximum inventories associated with radioactive particulates would be found in the target chamber shortly after the last experiment and well before cleanup. By the time cleaning occurs or components are removed, the radioactive particulate inventory would have decayed to much smaller quantities.

The inventories provided for the analysis in Section M.5 are maximum additional inventories that would be required for the Proposed Action. For nonplutonium experiments, the inventories correspond to a final 45-megajoules-yield experiment, ending one year of experiments with 1,200-megajoules total yield. Experiments of this magnitude (45 megajoules) would not be scheduled as part of the normal experimental plan. However, 45 megajoules is the maximum credible yield that could be obtained. The 45-megajoules inventories are used here to bound all inventories of radioactive particulates and fission products. Table M.3.2.1–1 presents the maximum inventory of beryllium, lithium hydride, depleted uranium, highly enriched uranium, and tracer elements over the maximum inventory associated with the Proposed Action.

TABLE M.3.2.1–1.—*National Ignition Facility Inventories for Proposed Materials*

Material	Maximum Inventory
Beryllium	20 g
Lithium hydride/Lithium deuteride	125 g
Depleted uranium	100 g/yr[a, b]
Plutonium	3 g
Highly enriched uranium[c]	100 g
Thorium-232	450 g
Tracer elements, (iodine is representative)[d]	0.1 g

Source: LLNL 2003d.

[a] The single-experiment inventory limit results from the fission products created during a single high-yield experiment (45 MJ), as well as buildup of the longer-lived fission products during one year of 1,200-MJ operation.

[b] This is the total quantity of depleted uranium that could be in the National Ignition Facility target chamber at any one time. Individual targets for yield experiments would be limited to 2.2 g for depleted uranium.

[c] Assumed composition, by weight, is 93.5 uranium-235, 5.4 % uranium-238, and 1.1 % uranium-234. Individual targets for yield experiments would be limited to 1.2 g for highly enriched uranium.

[d] Other possible tracer elements include: beryllium, lithium, oxygen, neon, chlorine, argon, titanium, chromium nickel, copper, arsenic, bromine, krypton, rubidium, yttrium, zirconium, niobium, molybdenum, rhodium, silver, iodine, xenon, neodymium, samarium, europium, thulium, lutetium hafnium tantalum, tungsten, rhenium, iridium, gold, thallium, bismuth These are bounded by the representative tracer and could be used in similar quantities. The quantity in the table assumes 60 experiments/yr, each at 1.7 mg.

g = gram(s); yr = year.

Releases of activated target bay gases would be unchanged for the Proposed Action; however, some fission products would be created during experiments involving fissile or fissionable materials without an inner containment vessel, and some would be eventually released to the environment as part of normal operations. Many are short-lived and would decay while being held on the cryopumps. Alternately, they could be discharged to the accumulation tank and held until most have decayed. Some longer-lived gaseous fission products, such as krypton-85 (10.7 years half-life), would not have decayed by much when they would likely be released to the environment. Fission products that are solids (very small amounts) would be retained in the target chamber. Other semivolatile fission products, such as iodine isotopes, would be captured on charcoal filters, thereby minimizing any release of these radionuclides to the environment.

Personnel Exposure

Personnel would be exposed to prompt radiation during the NIF yield operations. Also, during yield operations, tasks that must be performed within the NIF target bay or that involve handling of materials that have been inside the target bay during high-yield experiments would result in some level of radiation dose. This would not change from the No Action Alternative.

In addition, a worker dose would be incurred during routine decontamination activities. This would include handling of contaminated/activated items; disassembling them, if needed; and processing them through the decontamination systems. This dose would be largely related to the cleaning frequency, which is unchanged from the No Action Alternative (once per year). Therefore, this component of the worker dose is not expected to change for the Proposed Action.

Radiation exposure in radiologically controlled areas would be kept as low as reasonably achievable through facility and equipment design and administrative controls.

M.3.2.2 *Transport of Materials*

NIF targets would come from more than one source. Most of the targets would be provided from an onsite source, such as the LLNL Tritium Facility. The other fabrication source would be Los Alamos National Laboratory in New Mexico. Targets for the Proposed Action would include quantities of depleted uranium, highly enriched uranium, thorium-232, or weapons-grade plutonium, in addition to tritium. An additional bounding scenario for the Proposed Action analysis would be the transport of one plutonium target (up to 3 grams) from its source. Post-experiment, the inner containment vessel would be transported onsite from the NIF to the Tritium Facility.

M.3.2.3 *Waste Generated During National Ignition Facility Operations*

Many of the waste streams described under the No Action Alternative would be unchanged for the Proposed Action, as they are not directly related to the proposed changes in materials used for experiments. Because fission products could be produced from some yield experiments, it is expected that there would be a small increase in LLW related to filters. Charcoal filters would be used to capture iodine isotopes, and these would need periodic, though infrequent, replacement. Other waste streams, such as the target chamber hardware or decontamination wastes, would not be expected to change because the cleaning frequency would be the same as under the No Action Alternative.

For plutonium experiments with containment, disposal of the inner containment vessel would substantially increase the low-level radioactive waste stream. The additional waste has been estimated based on 14 plutonium experiments per year: 4 with fusion yield and 10 without yield. Each inner containment vessel would occupy approximately 8.5 cubic meters of space, including void volume. Because it is expected, in most cases that the inner containment vessel would leave LLNL from the Tritium Facility, the waste would appear in the Tritium Facility (Building 331) waste stream. It is expected that only LLW would be generated as a result of using the inner containment vessel. Section M.5 provides details concerning the estimated waste streams for the Proposed Action.

M.3.2.4 *Neutron Spectrometer*

During the commissioning phase of the NIF, when full laser energy is not available, sub-ignition inertial confinement fusion experiments could be performed using targets that generate low neutron yields. Furthermore, non-inertial confinement fusion experiments are planned for the NIF that would require sensitive neutron diagnostics. A neutron spectrometer capability would more accurately measure neutron yield and diagnose ignition target physics.

The Proposed Action would include the construction and operation of a neutron spectrometer to provide an accurate measure of neutron fluxes in yield experiments. Similar underground construction was done at the University of Rochester Omega laser and at the LLNL Nova laser[5]. The neutron spectrometer construction would not start before fiscal FY2008 and when completed would become part of the NIF operational facility. The eventual design of the neutron spectrometer would depend greatly on the continuing development of detector technologies and the selected imaging technology. Conservative assumptions have been made using past and existing neutron spectrometer measurement systems.

The neutron spectrometer would be contained in a shielded-concrete shaft that would extend underground outward from the NIF target chamber (Figure M.3.2.4–1). The construction of the neutron spectrometer would require excavating and installing a concrete shaft from the target chamber to a point 52 feet below the surface. The shaft would contain approximately 1 cubic meter of solid plastic scintillator (polyvinyl toluene) and would be shielded by approximately 20 tons of lead. The bottom of the shaft would be near the water table. The plastic scintillator, in the form of thin sheets, would be held in a rack at the bottom of the shaft. The shaft would be sealed to prevent contamination of groundwater from any leakage from the shaft or any inflow into the shaft. The design and construction of the shaft would prevent groundwater intrusion.

M.3.3 Reduced Operation Alternative

Under the Reduced Operation Alternative, the neutron spectrometer would not be constructed and there would be no experiments with plutonium; other fissile materials; fissionable materials, other than depleted uranium without yield; or lithium hydride. The operation of the NIF under the Reduced Operation Alternative would be similar to that under the No Action Alternative. The primary difference would be in the schedule of experiments, the annual yield, and tritium throughput. The tritium throughput would be reduced from 1,750 curies per year to 1,500 curies per year.

Annual yield from the NIF ignition experiments would be reduced by 33 percent under the Reduced Operation Alternative, from 1,200 megajoules per year to 800 megajoules per year. The individual experiment yields would remain at up to 20 megajoules (45 megajoules maximum credible yield), but the total number of experiments with high yield would be reduced.

[5] Nova laser was decommissioned in May 1999.

This effectively limits the number of experiments that use ignition to produce the physics data needed to support Stockpile Stewardship Campaign milestones. Some aspects of operations would be affected by the stretching of the experiment schedule. These aspects are discussed individually in this section. The differences in operating parameters among No Action Alternative, Proposed Alternative and Reduced Operation Alternative are presented in Table M.3–1.

The effect of the Reduced Operation Alternative would be to stretch out experimental deliverables by an increasing amount over time in proportion to the reduced yield limits each year. Over a 10-year period, this would correspond to an approximately 3-year addition to the schedule to achieve the same deliverables for Stockpile Stewardship as compared to the No Action Alternative and Proposed Action. In the shorter term, the Reduced Operation Alternative would delay the availability of experimental data needed to optimize the NIF laser and ignition target parameters leading to the achievement of fusion ignition on the NIF. The Reduced Operation Alternative would delay the time when ignition physics data could be made available to benchmark and validate accelerated strategic computing initiative computer codes used for modeling nuclear weapons behavior. The reduced annual yield would also reduce the number of weapons effects tests that would require the intense amount of neutron and x-ray radiation generated by ignition targets and used to test the radiation hardness of military systems and components.

By maintaining the full operations and support facilities staff, the facility would be in complete operational readiness, and the annual yield could be raised to either the No Action Alternative or Proposed Action level of 1,200 megajoules per year and the tritium throughput to 1,750 curies per year.

M.3.3.1 *National Ignition Facility Operations*

The laser and target area building is an environmentally controlled clean room facility housing the laser and target area systems and the integrated computer system. The majority of the building is dedicated to providing the laser power, radiation confinement and control, and all necessary system control and diagnostics. It consists of two laser bays, two optical switchyards, a target chamber in a shielded target area, target diagnostic facilities, capacitor areas, control rooms, and an operations support areas, see Figure M.1.2–1. This equipment and these operations are necessary to operate the NIF for even one experiment. Under the Reduced Operation Alternative, the equipment and operations would be the same as those described for the No Action Alternative in Section M.3.1.1.

The diagnostic building, adjacent to the target bay, houses the environmental protection systems, target receiving area, tritium processing area, and diagnostic support areas. The tritium processing system would operate by oxidizing gaseous tritium and capturing the oxidized tritiated water on molecular sieves. These operations also would be necessary for staging each experiment. These operations would be identical to those described for the No Action Alternative; however, the amount of material captured by the filters and molecular sieves would be related to the number and type of experiments. Thus, the replacement of filters and decontamination of equipment would be reduced, along with the resultant waste streams.

Facility Utility Usage

Facility operations would require the use of electrical power, water, and natural gas and the discharge of wastewater. The NIF would use electricity to operate the laser and plant equipment necessary to support basic operations. The power would be used continuously for 8,760 hours per year, for a total energy consumption of 131,400 megawatt hours per year. This would include operations of the HVAC system, chilled and heated water systems, lighting, and facility heating. The power used to keep the NIF at clean room conditions would be much greater than the power used by the laser in an experiment. Therefore, utility usage would not be reduced under the Reduced Operation Alternative.

The two standby diesel generators would still be maintained in readiness and, under normal conditions, would be operated only for the purpose of maintenance and testing, about 10 hours per year.

M.3.3.2 *Laser Operations*

The operating parameters established for the NIF experiments under the Reduced Operation Alternative are indicated below.

- Laser power/energy to the target: 500 terrawatts/1.8 megajoules
- Maximum design yield per experiment: 20 megajoules (maximum credible yield would be 45 megajoules)
- Annual total yield: 800 megajoules per year

Otherwise the laser operations would be the same as described under the No Action Alternative in Section M.3.1.2.

M.3.3.3 *Target Bay and Target Chamber*

The target bay consists of the following major subsystems: target chamber, target emplacement positioner, target diagnostic control room, support structures, environmental protection, and vacuum and other auxiliary systems. The target bay and target chamber would be operated in the same manner as described under the No Action Alternative in Section M.3.1.3.

Some aspects of the target bay and target chamber operations are scalable to the number and type of experiments conducted and, therefore, would be less under the Reduced Operation Alternative, including the following:

- Generation of radioactive air emissions, such as activated air created during high-yield experiments or a tritium release
- Generation of solid LLW from replacement of the disposable debris shields, periodic cleaning the main debris shields, and the replacement and disposal, as needed, of the main debris shields and first wall panels due to damage or age
- Use of caustic chemicals for cleaning the main debris shields and first wall panels
- Replacement of the charge-coupled discharge cameras used for target chamber diagnostics
- Replacement of filters

M.3.3.4 *National Ignition Facility Experiments*

Both indirect-drive and direct-drive experiments could be conducted on the NIF under the Reduced Operation Alternative in the manner described for the No Action Alternative in Section M.3.1.4. The series of experiments conducted on the NIF to validate system operation and evaluate weapons data would proceed as described for the No Action Alternative. The NIF would be operated as a low-hazard, radiological facility under the Reduced Operation Alternative. Only the schedule for the experiments would be changed.

Radiation Produced from Experiments

The activation of target bay structures and concrete walls by neutrons from the NIF experiments and the skyshine produced by the neutrons would be less than projected for the No Action Alternative. Therefore, worker exposure would be lower under the Reduced Operation Alternative.

Tritium

Tritium would be transported, handled, and used in the same manner as under the No Action Alternative described in Section M.3.1.4. The amount of tritium in individual targets would not be expected to change for the Reduced Operation Alternative, containing up to 5 curies each 2 curies in the capsule and up to 3 curies in the associated hardware. If direct drive were implemented, each target would contain up to 70 curies. The annual tritium throughput at the NIF would be limited to 1,500 curies per year. The frequency of delivering tritium targets would be reduced by approximately 14 percent below the No Action Alternative level. The tritium in-process inventory limit for the NIF would still total no more than 500 curies.

Particulates

The generation of particulates in the target chamber is related to the number and type of experiments. Particulate generation would be less under the Reduced Operation Alternative than that discussed under the No Action Alternative in Section M.3.1.4. As the particulate material is exposed to neutrons from yield experiments, some would become activated and converted to radioactive material. The particulates would accumulate in the target chamber until the scheduled cleanup. At that time, the radioactive particulates created in the target chamber would be transferred to the decontamination systems and waste streams. Under the No Action Alternative, the cleanup was assumed to take place on an annual basis. Under the Reduced Operation Alternative, the cleanup would take place on an 18-month cycle. For the purpose of this analysis, the impacts associated with the cleanup have been annualized and are scalable as two-thirds those of the No Action Alternative.

M.3.3.5 *Hazardous Materials*

The main nonradiological materials at the NIF would include miscellaneous solvents and cleaning chemicals, decontamination process materials, fluids in electrical equipment, and materials that are part of, or placed into, the target chamber. The use of these and other materials needed to support the NIF operations would remain the same under the Reduced Operation Alternative as under the No Action Alternative (Section M.3.1.5).

The use of cleaning agents in the decontamination processes would be less under the Reduced Operation Alternative. A roughly one-third reduction on an annual basis would be seen in the use of these agents, including phosphoric acid, nitric acid, and sodium hydroxide.

The hazardous materials associated with the power conditioning units used in support of the pre-amplified modules would remain the same under the Reduced Operation Alternative.

The NIF would use beryllium in two forms: collected solids, primarily in filters, that cannot become particulate, and material in exposed diagnostics and targets that can become particulate. The NIF would handle small quantities of beryllium in the form of targets and windows for diagnostics. This would not change on a per target basis under the Reduced Operation Alternative. It is not anticipated that there would be significant airborne exposure to the workers. This would be confirmed by air monitoring. Surface swiping would be performed to confirm that surface beryllium contamination would remain within permissible housekeeping limits for beryllium work areas (10 CFR Part 850).

The composition of targets would be the same as for the No Action Alternative. The generation of debris from the target and hohlraum deposited on the target chamber wall and debris shields would be less on an annual basis than projected for the No Action Alternative. Under the No Action Alternative, the target chamber would only be decontaminated once per year. Under the Reduced Operation Alternative, the target chamber would be decontaminated once per 18 months. The inventory of particulates in the target chamber would be reduced by one-third, on an annual basis, from that of the No Action Alternative. There will be no explosive materials stored or used at the NIF.

M.3.4 Comparison of Alternatives and Environmental Impacts

Table M.3.4–1 compares the potential environmental consequences of the Proposed Action, and No Action Alternative, and Reduced Operation Alternative. The details of the environmental consequences, summarized in this table, are provided in Section M.5. The first column of the table provides information from the SSM PEIS environmental impacts. This information is provided to aid the reader in understanding the differences between the SSM PEIS and the No Action Alternative. This information is only provided as a reference. The No Action Alternative is the basis for comparison to the Proposed Action and the Reduced Operation Alternative.

Proposed Action Impacts

As indicated in the table, changes in Proposed Action impacts, as compared to the No Action Alternative impacts, would only occur in three areas. The impacts, while of concern, would not result in significant environmental consequences. The impacts would include an increased use of several hazardous and radiological materials, an increase in low-level solid radioactive waste generation from the use of these materials, and an increase in worker exposure.

Under the Proposed Action there would be an increase in the use of beryllium from 1.6 to 20 grams per year and the use of 125 grams of lithium hydride per year. The neutron spectrometer would also use 4,000 pounds of polyvinyl toluene and 43,000 pounds of lead for the detector. The No Action Alternative limit established for the use of beryllium would be 1.6 grams per year. The use of lithium hydride was not evaluated as part of the No Action Alternative.

Changes in the use of radiological materials under the Proposed Action would include the use of up to 3 grams of weapons-grade plutonium per experiment, 100 grams of highly enriched uranium per year, 100 grams of depleted uranium per year, and 450 grams of thorium per year. The radiological materials limit established under the No Action Alternative would be 5 grams of depleted uranium per year. The use of fissile and fissionable materials, described above, is not considered under the No Action Alternative. The use of tritium would remain the same as discussed under the No Action Alternative.

The low-level solid radioactive waste would increase from 70 cubic meters per year under the No Action Alternative to 190 cubic meters per year under the Proposed Action. The 190 cubic meters is nearly fifty percent of the estimated sitewide generation of low-level radioactive waste. These levels of waste generation are within the capacity for treatment, transportation, or storage. The other waste categories numbers would remain the same as the No Action Alternative numbers.

The estimated worker exposure for the NIF operations would be 19 person-rem per year for the Proposed Action. The No Action Alternative worker exposure would be 15 person-rem per year. The Proposed Action worker exposure of 19 person-rem per year is 15% of the LLNL estimated total worker population dose. The LCFs projected under the Proposed Action for the NIF would be 1.1×10^{-2}. The LCFs projected under the Proposed Action for LLNL would be 7.5×10^{-2}. No individual will receive more than 500 mrem/year.

Reduced Operation Alternative Impacts

The Reduced Operation Alternative impacts would be less than the No Action Alternative impacts in several areas. These would include a reduction in the use of hazardous and radiological material, a reduction in waste generation, and a decrease in worker exposure. Under the Reduced Operation Alternative, the neutron spectrometer would not be constructed and there would be no experiments with plutonium; other fissile materials; fissionable materials, other than depleted uranium; or lithium hydride.

M.4 DESCRIPTION OF THE AFFECTED ENVIRONMENT

M.4.1 Environmental Setting

Chapter 4 of the LLNL SW/SPEIS describes the environmental setting and existing conditions associated with current operations at LLNL. This information forms a baseline for evaluating the environmental impacts associated with implementing the No Action Alternative, Proposed Action, and Reduced Operation Alternative. Information from Chapter 4 of the LLNL SW/SPEIS was used as a basis for analysis of the impacts presented in Section M.5 of this appendix.

M.5 ENVIRONMENTAL CONSEQUENCES

The No Action Alternative, Proposed Action, and Reduced Operation Alternative are considered in this appendix. Section M.5 is broken into several subsections as follows:

- Section M.5.1 provides a short discussion of methodologies used to assess potential impacts. See the main document for additional information.
- Section M.5.2 discusses the impacts associated with the No Action Alternative and provides information from the SSM PEIS for comparison.
- Section M.5.3 presents the potential impacts that could occur under the Proposed Action involving the changes of the NIF operations associated with the use of plutonium, other fissile materials, fissionable materials, and lithium hydride/deuteride in experiments on the

NIF. In addition the section presents impacts associated with the construction and operation of a neutron spectrometer.

- Section M.5.4 evaluates the changes in impacts that would result from reducing operations on the NIF consistent with the Reduced Operation Alternative.
- Section M.5.5 discusses the mitigation measures.
- Section M.5.6 provides a discussion of the risks and consequences of accidents associated with the operation of the NIF.

M.5.1 Methodology

The evaluation of the No Action Alternative, Proposed Action, and Reduced Operation Alternative in this appendix was performed to provide the information and context with which the decision-maker could reach a decision that would be documented in the Record of Decision. The differences being considered in this appendix are related primarily to the experiments to be conducted on the NIF and their scheduling, not the operation of the NIF as a facility. The facility operations are discussed where the information aids in the understanding of issues being considered.

Some environmental resources are of lesser relevance to the impacts being assessed; the impacts of each environmental resource are evaluated and discussed to the degree that the resource could be affected by the Proposed Action, No Action Alternative, or Reduced Operation Alternative. If there would be little impact to or change in the environmental resource under each of the alternatives, the resource is discussed only briefly. A description of the methodology used to assess the potential impacts associated with each alternative is presented in Chapter 5.1 of LLNL SW/SPEIS. The methodology used for the NIF appendix is the same as that used in the LLNL SW/SPEIS and is not repeated.

M.5.2 No Action Alternative

The No Action Alternative would comprise the continued installation of equipment and operation of the NIF. Under the No Action Alternative, the estimated operating parameters for the NIF would be a maximum credible yield of 45 megajoules. The maximum annual total yield would be 1,200 megajoules per year. The maximum annual tritium throughput would be 1,750 curies per year with a maximum tritium inventory of 500 curies. Under the No Action Alternative, the NIF would perform the full ignition program required to meet the SSP but would not perform experiments with plutonium, other fissile materials, fissionable materials (other than depleted uranium), or lithium hydride. The neutron spectrometer capability would not be constructed. The NIF would continue to be operated as a low-hazard radiological facility.

M.5.2.1 *Land Use and Applicable Plans*

In general, land at and in the vicinity of LLNL is zoned for industrial park use. The industrial land use for the NIF was determined in the SSM PEIS. The NIF land use is compatible with LLNL land use. The No Action Alternative would not result in any change to the land use for the immediate area of the NIF or land use in the overall vicinity. No impacts to land use are expected from the No Action Alternative.

M.5.2.2 *Socioeconomic Characteristics and Environmental Justice*

Socioeconomics

The No Action Alternative would not include the construction of a neutron spectrometer; therefore, there would be no increase in temporary employment due to construction activities.

The employment numbers provided in the SSM PEIS were 330 long-term employees for operating the NIF. Current projections for the No Action Alternative are that 180 employees would be needed for direct operations along with 220 support personnel. Together, 400 long-term workers would be employed at the NIF and its support operations. Most of these workers are already employed at LLNL, either working on making the NIF operational or at other LLNL facilities. It is expected that up to 20 new hires would be needed to reach the 400 long-term employee level. Any new hires would fall within the 5 to 8 percent annual turnover at LLNL. Therefore, no impacts to local housing, schools, or medical services are anticipated.

Environmental Justice

The evaluation of Environmental Justice involves the identification of any disproportionately high and adverse human health or environmental effects of existing or approved projects, programs, policies, and activities on minority populations and low-income populations. There are no block groups within a 5-mile radius that are categorized as minority. There are no block groups within a 10-mile radius of the Livermore Site that have percentages of low-income populations greater than the state average. The impacts associated with the operation of the NIF with potential for disproportionate effects would be radioactive air emissions. Beyond a 5-mile radius these impacts would be negligible (see Section M.5.2.8). Therefore, there would be no disproportionately high and adverse impacts to minority or low-income populations from the No Action Alternative.

M.5.2.3 *Community Services*

The SSM PEIS projected that there would be an increased demand for general services, while there would be no change in fire or police services. The existing LLNL fire protection and emergency services and police protection and security services would not change under the No Action Alternative. The level of services provided currently would not change. Because there would be no substantial change in the workforce, there will be no changes in the socioeconomic impacts and no associated change in school services.

The NIF would not adversely affect the ability of Alameda County to provide adequate solid waste disposal. The SSM PEIS estimated that the NIF would generate 6,000 cubic meters of nonhazardous solid waste per year. This figure was overly conservative as it represented a doubling of LLNL generation of nonhazardous solid waste in 1994. LLNL's current generation of nonhazardous solid waste averages 0.5 cubic meter per person per year or approximately 4,600 cubic meters (LLNL 2002cc).

The NIF is generating and will continue to generate waste office paper, cardboard, plastic, sanitary wastes, and other nonhazardous refuse at a rate similar to the Laboratory as a whole. There is nothing unique about the refuse generation from the NIF, in terms of waste types or amounts; therefore, this type of waste is projected on a per capita basis. As a conservative estimate (current LLNL generation is 0.5 cubic meter per person), it is assumed that each worker would generate 1 cubic meter of nonhazardous solid waste. With a projected total of 400 long-term workers at the NIF and its support operations, the projected amount of nonhazardous solid waste would be approximately 400 cubic meters per year. Because 380 long-term personnel are already employed at NIF, the associated 380 cubic meters of nonhazardous solid waste is already part of the overall LLNL waste figures. The 20 new hires would generate a maximum of 20 cubic meters of additional nonhazardous solid waste per year. This amount is slightly more than a 0.4 percent increase in the site's generation of nonhazardous waste; therefore, no impacts are expected to the capacity to handle nonhazardous solid waste under the No Action Alternative.

M.5.2.4 *Prehistoric and Historic Cultural Resources*

The SSM PEIS projected that there would be no impacts to cultural resources from the construction and operation of the NIF. No prehistoric archaeological resources have been identified on or near the NIF site. No buildings and facilities at LLNL that could have potential to be eligible to the National Register of Historic Places are located near the NIF. Since much of the NIF site has been developed, the likelihood of finding unrecorded and undisturbed prehistoric sites is low. Under the No Action Alternative, the neutron spectrometer would not be built; therefore no excavation will be required. There would be no impacts expected to prehistoric or historic cultural resources from the No Action Alternative.

M.5.2.5 *Aesthetics and Scenic Resources*

With the exception of temporary dust and vehicle exhaust emissions from construction activities, the SSM PEIS projected no impacts to visual resources from the construction and operation of the NIF. The NIF conventional facility construction is now complete. All conventional facilities are constructed and turned over for equipment installation. No further changes to the visual features would occur in the area of the NIF. There would be no impacts to aesthetic and scenic resources under the No Action Alternative.

M.5.2.6 *Geologic Resources*

The SSM PEIS projected that 25 acres of land would be cleared for the construction of the NIF, with 5 acres being used for a construction laydown area. The SSM PEIS proposed that the laydown area would be restored after construction was complete. The conventional construction of the NIF is now complete. The laydown area is still being used to store and transfer equipment while the NIF is being made operational. Animal fossils have been found beneath the NIF; however, no new excavation is planned under the No Action Alternative. No further impacts to soils or fossils would result from the No Action Alternative.

M.5.2.7 *Ecology*

The SSM PEIS discussed the potential for construction of the NIF to affect the nearby wetland and the potential foraging habitat for the western burrowing owl. The SSM concluded that there would be no adverse impact to these resources from the construction and operation of the NIF.

NIF conventional facility construction is complete. No new construction would occur under the No Action Alternative; therefore, there would be no erosion or changes to existing stormwater flow patterns. No impacts would occur to the nearby wetland area. Few impacts will occur to biological resources during operation of the NIF. The traffic to and from the NIF would have associated losses of road-killed individuals of some species. No adverse impacts to threatened and endangered species or species of special concern would be expected from operation of the NIF.

M.5.2.8 *Air Quality*

During normal operations, some experiments at the NIF would result in atmospheric releases of small quantities of tritium and some radionuclides produced by activation of gases in the target bay air.

Some nonradiological hazardous materials would be present at the NIF. Routine emissions of these types of materials would be expected from operation of electrical equipment, wipe cleaning, and occasional use or maintenance testing of the standby generators. The projected air pollutant emission rates associated with increased fuel combustion in boilers and engines, and the increased vehicular activity associated with increased workforce at LLNL under the LLNL SW/SPEIS No Action Alternative, which includes the NIF, are provided in Chapter 5 of the LLNL SW/SPEIS text. The total emissions are a small fraction of project significance levels and threshold levels for conformity.

Criteria Air Pollutants

The U.S. Environmental Protection Agency has set national ambient air quality standards to protect public health, and the State of California has its own sets of standards, state ambient air quality standards, that are generally more stringent than the Federal standards. Air emissions are discussed below in terms of the Federal and state criteria air pollutants, which are ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter less than 10 microns in diameter (PM_{10}), and lead.

The SSM PEIS stated that air pollutant emissions from operation of the NIF would occur primarily from fuel combustion and solvent cleaning of the debris shields. The criteria air pollutants from fuel combustion for the operation of standby diesel generators for the NIF (Section M.5.2.12) are listed in Table M.5.2.8–1. The current projections for the NIF criteria air pollutant emissions are less than 3 percent of the SSM PEIS projections for PM_{10}, nitrogen dioxide, and sulfur dioxide. The NIF emissions of carbon monoxide would be 22 percent of the SSM PEIS projection. Only the projected emissions of volatile organic compounds (VOCs) would be greater than the rate projected in the SSM PEIS.

Under the No Action Alternative, the NIF would use VOCs for lens cleaning and other wipe cleaning operations in the clean-room environment. These solvents would include ethanol, acetone, and isopropanol. The use of such solvents would be limited to 400 gallons per year by the Bay Area Air Quality Management District's air permit (S-2121). Based on experience to date, it is estimated that the annual solvent usage would not approach 400 gallons per year. However, 400 gallons was used as a bounding quantity in Table M.5.2.8–1. This bounding quantity would represent a 15 percent increase in LLNL volatile organic compounds emission rate. Considering the quantities likely to be used, the potential use of dilute aqueous solvent solutions, and the potential use of other non-solvent cleaning techniques, the increase in VOCs emissions would likely be smaller.

TABLE M.5.2.8–1.—*Annual Emissions from National Ignition Facility Operations at Lawrence Livermore National Laboratory (No Action Alternative)*

Pollutant	SSM PEIS Projected NIF Emissions (t/yr)	2000 LLNL Emissions (t/yr)	Projected NIF Emissions (t/yr)	2000 LLNL Emissions Plus NIF (t/yr)	NIF Percent of 2000 LLNL Emissions
Particulate matter 10 microns or smaller	0.16	2.21	0.0042	2.21	0.19
Volatile organic compounds	0.56	7.87	1.18	9.05	15.0
Carbon monoxide	0.43	5.58	0.094	5.67	1.7
Nitrogen dioxide	1.79	21.6	0.076	21.7	0.35
Sulfur dioxide	0.03	0.241	0.0017	0.242	0.68
Lead	Negligible	Negligible	Negligible	Negligible	Negligible

Source: LLNL 2003d.
LLNL = Lawrence Livermore National Laboratory; NIF = National Ignition Facility; SSM PEIS = Stockpile Stewardship Programmatic Environmental Impact Statement; t/yr = tons per year.

The relatively small amount of solvent usage would probably not be affected by regulatory changes during the life of the project. If emission reductions are required in the future, they could be accomplished by a "capture/control" process employing carbon adsorption. The air district generally applies a "cost-effectiveness" criterion in deciding if the additional controls are warranted, and it is unlikely that such controls would be deemed "cost-effective." It is more likely that solvent usage reductions would be accomplished voluntarily, as a result of pollution prevention/solvent substitution efforts.

The NIF would generate criteria air pollutants during operation of the standby generators. The NIF has two standby diesel generators. Under normal conditions, the generators would be operated only for the purpose of maintenance and testing, for about 10 hours per year. Until recently, emergency standby generators were exempt from air permitting. The regulations were changed to require air permits, and existing generators (such as the two NIF generators) were "grandfathered" into the system of permitted sources. Air permits were received for the two generators in June 2002. The new air permits allow for unlimited operation during a power outage. A power outage is unlikely, because LLNL obtains power from two separate power suppliers. Therefore, air emissions resulting from a power outage are not included in Table M.5.2.8–1.

It has been the Bay Area Air Quality Management District's policy to allow new equipment to be used for a reasonable "useful life" before it must be replaced or retrofitted to reduce emissions. Because the NIF standby generators are relatively new, efficient units, it can be assumed that they would be allowed to be used for at least 10 years without changes. It is possible that they would be allowed to be used without modification for the life of the NIF; therefore, no projections have been made for replacements to the existing combustion equipment.

Hazardous Air Pollutants (HAPs)

The SSM PEIS stated that only minute quantities of hazardous VOCs would be expected to be emitted from the NIF. LLNL evaluates a list of approximately 200 compounds to confirm applicability under the National Emission Standards for Hazardous Air Pollutants (NESHAP). Emissions of hazardous air pollutants for all of LLNL are less than one-half of the thresholds of

7 tons per year for a single hazardous air pollutant or 15 tons per year for a combination of hazardous air pollutants (LLNL 2002ae). The normal operations of the NIF under the No Action Alternative would not result in the emission of hazardous air pollutants, except for the possible beryllium emissions as discussed in the next section.

Toxic Air Emissions

The SSM PEIS did not discuss toxic air emissions. LLNL compiles an inventory of toxic air contaminants under the California Air Toxics “Hot Spots” program. Of the more than 300 “Hot Spot” chemicals, only 3 are emitted at the Livermore Site at levels that exceed the health-risk-based *de minimis* reporting level (benzene, formaldehyde, and trichloroethylene). The NIF inventory would not include these chemicals. Under the No Action Alternative, the NIF would not increase the Livermore Site emission of these chemicals.

The use of beryllium in targets could result in airborne emissions from the NIF operations. Most of the contamination would be contained within the NIF target chamber. The bounding annual amount of particulate beryllium produced from the NIF operations in the target chamber would be 1.6 grams. This would represent the maximum inventory expected to be generated in any given year based on current plans for experiments and their associated targets and diagnostics. The projected air emissions of beryllium would be well below the Bay Area Air Quality Management District’s Toxic Air Contaminant threshold for beryllium of 0.015 pounds per year (6.8 grams per year). The toxic air contaminant threshold is used by the Bay Area Air Quality Management District as a guidance tool to determine the health significance of toxic air emissions. The NIF beryllium emissions would be filtered before discharge to the atmosphere and would remain well below the Bay Area Air Quality Management District’s toxic air contaminant threshold.

No increase in impacts from LLNL hazardous air pollutants and toxic air emissions would occur under the No Action Alternative. The increase in the emission of VOCs would be bounded at 15 percent. The impacts of the increase would be minor.

Radiological Air Quality

The SSM PEIS concluded that the general public living in areas surrounding LLNL site and LLNL workers could be exposed to small quantities of radionuclides released and radiation emitted from routine NIF operations, but that the expected level of radioactive releases and radiation emissions would be well within regulatory limits.

During normal NIF operations, experiments would result in atmospheric releases of small quantities of tritium and some radionuclides produced from activation of gases in the air. Table M.5.2.8–2 presents the maximum inventory of activated gases from the target bay air and the argon in the beam tubes generated from a single experiment. The total inventory of activated gases would correspond to a 45-megajoule maximum credible yield experiment. Experiments of this magnitude (45 megajoules) are not scheduled as part of the normal experimental plan. However, 45 megajoules is likely to be the maximum credible yield that could be obtained. The 45-megajoule inventory is used here to bound the inventory of activated material.

Because of the short half-lives of the radionuclides and the slow release of target bay air, only a small fraction of the inventory produced would be released to the environment. Negligible quantities of activated gases would be expected to be released from the beam tubes. The total annual inventories of radioactive gases that would be produced and emitted to the environment for 1,200 megajoules per year are provided in Table M.5.2.8–3.

TABLE M.5.2.8–2.—*Estimated Maximum Activated Gases Inventory per Experiment*

Isotope	Quantity (curies)
Target Bay Air	
Hydrogen-3	1.6×10^{-4}
Nitrogen-13	1.9×10^{1}
Nitrogen-16	3.2×10^{3}
Sulfur-37	4.2×10^{-1}
Chlorine-40	2.4
Argon-41	1.6
Carbon-14	4.9×10^{-5}
Beam Tubes	
Hydrogen-3	3.4×10^{-8}
Sulfur-35	3.4×10^{-6}
Argon-37	8.7×10^{-4}
Argon-39	1.2×10^{-4}
Argon-41	3.5

Source: LLNL 2003d.

These radionuclides would be released through the elevated release point, 35 meters aboveground. The release point is 1.1 meters in diameter and gases would exit at 7.3 meters per second. The maximally exposed individual (MEI) would be expected to be located at the offsite veterinary facility on Greenville Road, 350 meters from the elevated release point. Estimates of annual emissions of activated gases, based on 1,200 megajoules per year of yield, are provided in Table M.5.2.8–3. Up to 30 curies per year of tritium would be released during maintenance activities, when equipment is opened up or brought up to atmospheric pressure.

TABLE M.5.2.8–3.—*Annual Routine Radiological Airborne Emissions from the National Ignition Facility (No Action Alternative)*

Nuclide Produced	Nuclide Half-Life	Production (curies/year)	Emissions (curies/year)
Activated Air			
Hydrogen-3	12.33 yr	4.3×10^{-3}	4.3×10^{-3}
Carbon-14	5730 yr	1.3×10^{-3}	1.3×10^{-3}
Nitrogen-13	9.99 min	5.1×10^{2}	6.8×10^{1}
Nitrogen-16	7.13 sec	8.4×10^{4}	1.5×10^{2}
Sulfur-37	5.06 min	1.1×10^{1}	7.9×10^{-1}
Chlorine-40	1.42 min	6.4×10^{1}	1.3
Argon-41	1.83 hr	4.2×10^{1}	2.6×10^{1}
Tritium (releases during maintenance)			**30**

Source: LLNL 2003d.
hr = hours; min = minutes; sec = seconds; yr = years.

Table M.5.2.8–4 presents the potential impacts of radiological air emissions to the public. The total exposure to the MEI also would include a component from prompt radiation (0.2 millirem per year) as discussed in Section M.5.2.14.1. The prompt dose is important near the site boundary where the MEI would be located. The prompt dose is less important to the general population whose exposure to it would be either transitory or nonexistent. The population dose would be dominated by the radioactive airborne effluent emissions. While some of the radiation exposures from normal operations to workers would result from radiological air emissions, the doses to involved workers would be primarily from direct radiation exposure (see Section M.5.2.14.1). The impacts, as discussed in the SSM PEIS, are presented for comparison.

TABLE M.5.2.8–4.—*Radiological Impacts to the General Public from Airborne Effluent Emissions during Normal Operations (No Action Alternative)*

Receptor	No Action Alternative	
	Dose	Latent Cancer Fatality Risk
NIF offsite MEI	0.04 mrem/yr	2.4×10^{-8}/yr of exposure
Population Dose	0.26 person-rem/yr	1.6×10^{-4}

Source: LLNL 2003d.
MEI = maximally exposed individual; mrem = millirems; NIF = National Ignition Facility; yr = year.

The site-wide MEI is a hypothetical individual who spends 24 hours per day, 365 days per year, at the publicly-accessible location where they would receive the greatest dose from LLNL operations. The location of the site-wide MEI would correspond with the NIF MEI location. The baseline dose to the MEI from Livermore Site operations (site-wide MEI) without the NIF operations was 0.017 millirem per year with an associated population dose of 0.16 person-rem per year in 2001 (LLNL 2002cc). Due to planned increases in Building 331 tritium releases, the No Action Alternative dose to the site-wide MEI without the NIF operations would be expected to be 0.039 millirem per year. Conservatively, adding the site-wide MEI No Action Alternative dose to the NIF MEI dose for airborne emissions would result in an estimated dose of 0.079 millirem per year for airborne releases under the No Action Alternative. This dose would be less than 0.8 percent of the NESHAP limit. The component of population dose from routine NIF releases would be 0.26 person-rem per year. Adding this dose to LLNL SW/SPEIS No Action Alternative population dose of 0.89 person-rem per year would result in a dose of 1.15 person-rem per year. This population dose would be many orders of magnitude less than the dose received from natural background. No adverse impacts on radiological air quality would be expected from the NIF No Action Alternative.

M.5.2.9 *Water*

Under the No Action Alternative, the neutron spectrometer would not be built; therefore, there would be no changes to stormwater flow and no impacts to surface water or groundwater resources from construction activities.

The SSM PEIS projected an annual water usage at the NIF of 152 million liters per year, or approximately 4 percent of LLNL water supply capacity. The LLNL usage of 967 million liters per year in 1995 represented use of approximately 24 percent of LLNL's capacity. The SSM PEIS projected that there would be no impact to water quality or availability from the operation of the NIF.

Water usage at the NIF is currently expected to be 27.6 million liters per year, or approximately a 3.5 percent increase in LLNL usage of 795 million liters per year in 2001. Water used for the NIF operations would be supplied from the Livermore Site water system. The NIF water use would be within LLNL system capacity and no new wells or other sources would be required. Because no expansion of capacity would be required, there would be no impacts associated with expansion of capacity. The impacts of the increase in water use would be negligible in nondrought years. During drought years, the impacts of this increase in water use at LLNL would be of concern.

M.5.2.10 *Noise*

The SSM PEIS discussed the noise from construction of the NIF as the source of the greatest impact to an offsite individual. Noise from operation of the NIF was not discussed. Under the No Action Alternative, there would be no new construction or any demolition.

The main sources of noise from the operation of the NIF would be the vacuum pumps, HVAC systems, and traffic associated with moving equipment and truck deliveries. The noise level would be bounded by that of an industrial facility (approximately 85 decibels). The noise at the NIF would be equal to other local industrial/commercial activities; however, because of the size of LLNL site, the perimeter buffer zone, and intervening roads, the contribution of these activities to offsite noise levels would be small. These activities would not be in conflict with land-use compatibility guidelines. The impulse noise resulting from the NIF experiments would primarily come from the triggering of the capacitors. The noise would be able to be heard outside the NIF building for a short distance only. This noise is momentary and intermittent, occurring only at the time of an experiment, up to 6 times per day. No offsite noise would result from the experiments. The impacts of noise to workers would be normal for industrial facilities. With standard hearing protection, no impacts from noise would be expected. No impacts would be expected from noise to the public.

M.5.2.11 *Traffic and Transportation*

Traffic

The SSM PEIS evaluated the traffic impacts associated with an increase in employees at LLNL from the construction and operation of the NIF. An increase of 470 personnel, with an associated increase of 902 new vehicle trips per day, would result in a projected increase in traffic along local roads. The SSM PEIS projected a 10-percent increase along Patterson Pass Road, a 3- to 6-

percent increase along Vasco Road, a 3- to 4-percent increase along Tesla Road, and a 2- to 3-percent increase along First Avenue and Greenville Road.

The construction of the NIF conventional facilities is completed. As a result, the traffic associated with the construction workers has ceased. The personnel who are working to make the NIF operational and who will operate the NIF are already employed onsite. Therefore, there would be no change in the amount of traffic that currently exists.

Radiological Transportation

The consideration of target fill activities and the exact facilities that would perform these activities have not yet been fully decided. These activities would undergo NEPA and safety reviews prior to initiation of activities. Most of the targets would be provided from an onsite source. Routine onsite transportation of targets would have no impact to the public, as access to LLNL is restricted. The onsite transportation would fall within the scope of operational activities already analyzed for the site and the NIF in particular.

The major offsite source of target material would be Los Alamos National Laboratory. For purposes of analysis, under the No Action Alternative, 5 shipments per year, each with 0.2 grams of depleted uranium, and 15 shipments per year, each with 100 curies of tritium, would occur. The radiological transportation analysis is based on the assumption that these would all be separate shipments.

For incident-free transport; i.e., no accidents, of depleted uranium, the consequence would be the radiation dose potentially received by the truck drivers and members of the public driving on the highways, living near the highways, and present at rest stops. Because of the very small amount of radioactive material being transported and the shielding of the containers and truck, the radiation dose rate near the truck is expected to be immeasurably small. Therefore, there would be no incident-free radiation dose to drivers or members of the public.

Tritium does not produce an external dose rate. Therefore, transport of tritium would also have no incident-free radiological impacts. Section M.5.6 presents the consequences of transportation accidents, including tritium transport accidents.

M.5.2.12 *Utilities and Energy*

The NIF would be operated at clean-room conditions irrespective of the number of experiments. The utility usage at the NIF would be dominated by the operation of the facility at temperature stable clean-room conditions. Changes in the number and type of experiments would not change the overall utility usage.

M.5.2.12.1 *Water Use*

Water availability is discussed in Section M.5.2.9. The SSM PEIS projected that the NIF would have an annual usage of 152 million liters of water. Water usage at the NIF is currently expected to be 27.6 million liters per year, or approximately a 3.5-percent increase in LLNL usage.

Water would be used at the NIF for a variety of operations, including boilers, cooling towers, domestic use, landscape irrigation, washing, and fire hydrant testing. Some of the wastewater would be evaporated to the atmosphere, while other water would be discharged to the sanitary sewer or storm drain, as appropriate. A water balance for LLNL has been developed from several years of experience, which provides the discharge pathways for various water uses. The LLNL water balance was used to estimate the water/wastewater pathways for the NIF. An estimated breakdown of water use is presented in Table M.5.2.12.1–1.

TABLE M.5.2.12.1–1.—*Projected National Ignition Facility Water Use and Sewer Discharges*

Water Use Type	Water Usage (kgal/day)	To Sewer (kgal/day)
Sanitary	6.2	4.4
Process	4.0	3.9
Washing	1.0	0.90
Landscape irrigation	8.0	0.0
De-ionized water	0.75	0.34
Fire hydrant testing	0.05	0.0
Total (Kgal/day)	20.00	9.54
Total (MLY)	27.6	13.2

Source: LLNL 2003d.
Kgal = thousand gallons; MLY = million liters per year.

The current projected NIF water requirement and sanitary wastewater flow estimate are provided in Table M.5.2.12.1–2. Sanitary wastewater and sewer discharges are discussed in Section M.5.2.12.2. The LLNL water supply capacity would be sufficient to meet the requirements of the NIF; therefore, there would be no impacts associated with the NIF water consumption.

TABLE M.5.2.12.1–2.—*Water and Wastewater Utility Capacity at Lawrence Livermore National Laboratory*

Utility System	Current Usage	NIF Requirement	Projected Usage, Including NIF	Current Capacity
Water supply (MLY)	981	27.6	1009	3,980
Wastewater treatment (MLY)	354	13.2	367	2,340

Source: LLNL 2003d.
MLY = million liters per year; NIF = National Ignition Facility.

M.5.2.12.2 *Sewer*

The SSM PEIS projected the sanitary wastewater treatment requirement for the NIF as 18 million liters per year, or approximately 0.8 percent of LLNL treatment capacity in 1995. The 402 million liters generated at LLNL in 1995 represented approximately 18 percent of LLNL treatment capacity.

The currently projected wastewater treatment requirement for the NIF is 13.2 million liters per year, an increase of 5.2 percent from the 354 million liters per year currently generated at LLNL. The projected sanitary wastewater treatment requirement from the NIF would be within LLNL capacity for treatment. Much of the workforce to operate the NIF is already at work at LLNL and the associated sanitary wastewater generation has already been accommodated by LLNL treatment system. No new treatment facilities or ponds would be required, therefore, there would be no impacts associated with NIF sanitary wastewater and sewer discharges.

M.5.2.12.3 *Electrical Usage*

The SSM PEIS only considered availability of electrical power infrastructure. It did not project the amount of power that would be used. The NIF would use electricity to operate plant equipment to support basic operations. This would include operation of the HVAC system, chilled water systems, lighting, etc., and operation of the laser equipment; e.g., charging capacitors, operating the control room, and aligning lasers.

The original electric power requirement for the NIF was established by the NIF architecture/engineering firm, Parsons, to be 14 megawatts, or 1.23×10^8 kilowatt-hours per year. In subsequent design, this projection was increased by 7 percent to 15 megawatts, or 1.31×10^8 kilowatt-hours per year. This increase is primarily due to the addition of a new "clean dry air" system. In 2001, electrical power use at the Livermore Site was about 3.12×10^8 kilowatt-hours per year (LLNL 2002dl), with a peak usage of 54 megawatts. The NIF would result in a 42-percent increase in annual power usage over 2001. This would be a substantial increase in electrical usage. The LLNL peak usage would be projected to rise to 77 megawatts (LLNL 2002h). The current system's peak capacity is 125 megawatts.

M.5.2.12.4 *Fuel/Natural Gas*

The SSM PEIS projected that the NIF would use natural gas-fired boilers for HVAC and domestic hot water. The SSM PEIS projected that 2.14×10^7 megajoules (2.03×10^5 therms) of natural gas would be used annually for HVAC and domestic hot water for the NIF. Current projections for natural gas use have not changed. The natural gas usage at the NIF would represent a 2.6-percent increase over LLNL 2001 usage. This would be a minor impact to natural gas usage at LLNL.

The NIF standby generators would be operated by diesel fuel. These generators would be needed only to support key systems in the event of loss of primary power. These generators would be started up and tested/maintained regularly (~10 hour per year); but, because they normally would not be operational, fuel consumption would be low. The SSM PEIS projected an annual consumption of 85 gallons (320 liters) of diesel fuel for the NIF. No impacts are expected from the use of this small amount of diesel fuel.

M.5.2.13 ***Materials and Waste Management***

NIF research activities would use a variety of hazardous (radioactive and toxic) materials and nonhazardous materials. No explosive materials would be used at the NIF. All of these would become part of material management for the NIF. Once the materials have been used, they would be classified and managed under the NIF's and LLNL's waste management procedures. Waste management is discussed in Section M.5.2.13.3. During the use and management of these materials, air emissions would occur. Emissions are discussed in Section M.5.2.8.

Particulates would be generated in the target chamber by the melting and vaporization of target material and ablation of the first wall surface, debris shield, and other components within the target chamber. Some of these particulates would be radioactive; some would be hazardous or toxic. Particulates and debris collected during the annual cleanup of the target chamber would be added to the waste streams as discussed in Section M.5.2.13.3. The management of the radioactive particulates and tritium is discussed in Section M.5.2.13.1. Nonradiological materials are discussed in Section M.5.2.13.2.

The primary strategy for the control and management of hazardous materials at the NIF would be to minimize exposures to hazardous substances in accordance with the regulatory requirements, institutional goals, and best management practices by seeking less hazardous substitutes and ensuring safe handling and storage and proper disposal. Practices for material management at the

NIF would include personnel training, inventory control and monitoring, safety assessments, and waste handling. Additionally, standard operating procedures, specific operating procedures, and operating instructions would be prepared for specific activities to establish safe procedures, barriers, and controls and safe work practices with regard to hazardous material operations, including material use and storage.

M.5.2.13.1 *Radionuclide Materials Management*

Under the No Action Alternative, the NIF would use targets that could contain radioactive materials, including depleted uranium and tritium. The amount of material would vary according to each test.

During the NIF yield experiments, all materials in the target bay would be subject to neutron activation. This would include the target chamber walls, vacuum systems, air handling systems, equipment, shielding, filters, facility walls, roof and floors, room air, and support structures including optics and beam lines. Any particulates, adherent material, and target debris left in the target chamber from previous experiments could, in turn, be exposed to neutrons, energetic particles, debris, and x-rays from subsequent experiments. Neutron exposure from yield experiments would result in some of the material and debris from the previous experiment becoming activated. The particulates would accumulate in the target chamber until the scheduled annual cleanup. Exposure to the particulate prior to annual cleanup would be managed to minimize exposure. The radioactive particulates created in the target chamber would be transferred to the decontamination systems and waste streams during cleanup. However, because these are mostly short-lived species, the maximum inventories would be found in the target chamber shortly after the last experiment and well before cleanup. By the time cleaning occurs or components are removed, the radioactive particulate inventory would have decayed to much smaller quantities.

Table M.5.2.13.1–1 lists the prominent radionuclides expected to result from neutron exposure of particulates in the target chamber. The total inventory of activated, mobilizable particulates created in the target chamber would be quite small, but it is included here for completeness. The inventories in Table M.5.2.13.1–1 would be maximum inventories. They would correspond to a final 45-megajoule experiment (maximum credible yield), ending one year of experiments with 1,200 megajoules total yield. The 45-megajoule inventories are used here to bound inventories of activated material.

Depleted Uranium

Depleted uranium would arrive at the facility in individual targets, each with up to 2.2 grams of depleted uranium. The maximum annual depleted uranium throughput at the NIF under the No Action Alternative would be limited to 5 grams. Depleted uranium would be used only in nonyield experiments and would not be considered "activated," and no fission products would be produced. Depleted uranium is already slightly radioactive; the half-life of uranium-238 (dominant isotope) is 4.5×10^9 years. Depleted uranium is also considered to have toxic properties.

components would be removed during the decontamination process. This would transfer a small amount of tritium to the waste stream. The emissions of tritium are addressed in Section M.5.2.8.4.

M.5.2.13.2 *Nonradiological Materials Management*

The main nonradiological materials at the NIF would include miscellaneous solvents and cleaning chemicals, decontamination process materials, fluids in electrical equipment, and materials that are part of, or placed into, the target chamber. Other materials needed to support the NIF operations would include inert gases (argon) for laser operations, nitrogen for cryopumps, and other chemicals for general use. Some of these materials would be regularly consumed; others could be expended and require replacement during the lifetime of the NIF. These materials would then become part of the waste stream. Waste is discussed in Section M.5.2.13.3.

Nonradiological particulates will be generated in the target chamber from experiments. During the annual cleanup of the target chamber, the particulates and debris will be added to the waste streams discussed in Section M.5.2.13.3. Some of these particulates will be toxic. Based on the expected experimental campaign for the NIF, a total amount of ablated material per experiment was calculated. Table M.5.2.13.2–1 presents the bounding annual amount of particulate material produced from the NIF operations in the target chamber. This represents the maximum inventory that would be generated in any given year based on current plans for experiments and their associated targets and diagnostics.

A summary of nonradiological materials that would be used at the NIF is provided in Table M.5.2.13.2–2 along with applicable exposure criteria and maximum facility inventories. The NIF would use volatile organic solvents for lens cleaning and other wipe cleaning operations in the clean-room environment (see Section M.5.2.8.1). The handling, storage, and use of these materials would be managed to minimize exposures.

Throughout the Laser and Target Area Building, small quantities of various cleaners, oils, and miscellaneous other materials would be needed. These are not specifically listed in Table M.5.2.13.3–2, as the quantities and hazard level are bounded by other materials listed.

Each of the power conditioning units used to support the preamplifier modules would have a set of ignitron switches, which would contain 0.018 liter of mercury. A total of 3.5 liters of mercury would be contained in the 192 switches used at the facility.

The Optics Assembly Building would have a small inventory of chemicals, primarily used for cleaning. The main agent currently used (Brulin 815 GD) contains no hazardous ingredients, according to its Material Safety Data Sheet, and is generally approved for discharge to the sewer. The other chemicals listed would be stored in small quantities at the facility. Acetone and ethanol would be used only for occasional spot cleaning. Clean-room wipes, presaturated with 9-percent isopropanol in de-ionized water, would be used more frequently, but also in small quantities. The power for the NIF laser would be supplied by discharging a bank of capacitors. These capacitors would contain castor oil, which is nontoxic.

TABLE M.5.2.13.2–1.—*Bounding Annual Nonradiological Particulate Inventories in the Target Chamber (No Action Alternative)*

Material	Maximum Inventory (grams)
Aluminum	2.1×10^3
Gold	4.0×10^1
Beryllium	1.6
Copper	1.7×10^2
Dysprosium	2.1
Iron	2.6×10^2
Gadolinium	2.0×10^1
Germanium	2.0×10^1
Lead	3.0×10^1
Scandium	7.0
Silicon	5.0×10^2
Tantalum	2.9×10^1
Titanium	1.0×10^1
B4C	1.1×10^3

Source: LLNL 2003d.

M.5.2.13.3 *Waste Management*

At the NIF, waste management activities would consist of managing, storing, and preparing wastes for transfer to LLNL waste management facilities in accordance with applicable Federal and state regulations, permits obtained under applicable regulations, and DOE orders. The waste categories routinely generated by activities associated with the NIF under the No Action Alternative would include radioactive waste; i.e., LLW and mixed LLW (MLLW])[6]; hazardous waste, which would include *Resource Conservation and Recovery Act* hazardous waste, state-regulated waste, and *Toxic Substances and Control Act* waste; and nonhazardous solid waste and process wastewater. The wastes in this section are discussed in terms of the activities that generate them. Each description breaks out the amounts of LLW, MLLW, hazardous, and nonhazardous wastes.

The approach used in this section was to use the SSM PEIS estimates as a point of reference, and to make changes as appropriate, based on new quantitative information. Where there is uncertainty about potential reductions from the SSM PEIS estimates, the SSM PEIS estimates were retained, thereby providing a "contingency" to address the uncertainties in the estimates. Table M.5.2.13.3–1 summarizes the estimated waste streams under the No Action Alternative. The waste associated with the cleanup of the target chamber, i.e., particulates, discussed in Section M.5.2.13.1, is included under chemical treatment/decontamination.

[6] MLLW is low-level radioactive waste containing a *Resource Conservation and Recovery Act* hazardous chemical.

TABLE M.5.2.13.3–1.—*National Ignition Facility Waste Estimates for Low-Level, Mixed, and Hazardous Wastes (Annual) under the No Action Alternative*

Source of Waste	Low-Level Radioactive		Mixed		Hazardous	
	Solid (m^3)	Liquid (m^3)	Solid (m^3)	Liquid (m^3)	Solid (m^3)	Liquid (m^3)
SSM PEIS Total/yr	6.65[a]	1.6	0.9	5.0	8.0	4.6
Tritium processing	3.2	–	0.003	–	–	–
Wipe cleaning	3.3	0.3	1.0		1.0	–
HEPA filters/pre-filters	0.23	–	–	–	–	–
Waste hardware	63	–	0.5	–	–	–
Chemical treatment/decontamination	–	1.3	0.3	4.9		1.5
Waste oils/equipment	0.06	–	–	0.2	7.5	0.2
General chemicals	–	–	–	–	–	4.6
Total/year	70	1.6	1.8	5.1	8.5	6.3

Source: LLNL 2003d.
[a] Does not include debris shields.
HEPA = high-efficiency particulate air; m^3 = cubic meters; SSM PEIS = Stockpile Stewardship Management Programmatic Environmental Impact Statement.

M.5.2.13.3.1 *Radioactive and Mixed Waste*

Wastes from the Tritium Processing System

The tritium processing system would operate by oxidizing gaseous tritium in a reactor and capturing the oxidized tritium on molecular sieves. Wastes from this source would consist of 9 to 10 waste molecular sieve canisters per year from the tritium processing system module, replacement of the preheater reactor every 10 years, replacement of gloves on glove boxes every 6 months, and replacement of metal bellows pumps every 10 years. The SSM PEIS estimated this waste stream as 0.98 cubic meters per year of solid LLW. An additional waste stream of palladium catalysts, 0.003 cubic meters per year, which is assumed to be a mixed solid waste, has also been identified. Current estimates would be to replace 32 molecular sieve canisters per year, increasing this waste stream to 3.2 cubic meters per year of solid waste.

Waste from Wipe Cleaning, Chemical Treatment, and Decontamination

The wipe-cleaning waste would result from worker-protection personal protective equipment and the waste wipes and solvents associated with manual wipe cleaning of the NIF materials. The optics assembly building and the laser and target area building would conduct solvent wipe cleaning as part of the general clean-room operations. Usually, the solvent used would be isopropyl alcohol, although ethyl alcohol and acetone could be used at times. Most of the solvent wipe cleaning would be done with an aqueous solution of isopropyl alcohol, with 9-percent alcohol concentration. Used wipes with a concentration less than 24-percent alcohol are not a hazardous waste. In some cases, the wipes could be laundered and recycled. Used, wet wipes from aqueous solutions above 24 percent would be managed as hazardous waste, or mixed waste, as appropriate. Components entering the target chamber would also receive some surface tritium contamination. The decontamination process would transfer small amounts of tritium to the chemical treatment and decontamination waste streams.

The wipe cleaning waste estimates include 3.3 cubic meters per year of solid LLW, 0.3 cubic meters per year of liquid LLW, 1.0 cubic meter per year of solid MLLW, and 1.0 cubic meters per year of hazardous solid waste.

Chemical treatment and decontamination wastes would be created during the cleaning of the first wall panels in the target chamber and the main debris shields and associated hardware. Alternative cleaning methods considered include carbon dioxide snow cleaning, laser cleaning, ultrasonic cleaning, and chemical treatment. The current recommended method is chemical treatment, using an acidic bath for the first wall panels and a caustic bath for the main debris shields. Both of these processes would require rinsing after the chemical treatment. If acid foam is used, it would be followed with an aqueous rinse. In both cases, the chemical treatment and rinsing would generate a liquid LLW or a mixed waste. It is assumed that waste liquid from the chemical baths would be mixed waste, and waste rinsate would be LLW. The cleaning baths would be recirculated and filtered, and the solid filters would be disposed of as mixed solid waste. Waste estimates are 1.3 cubic meters of liquid LLW, 0.3 cubic meter of solid MLLW, 4.9 cubic meters of liquid MLLW, and 1.5 cubic meters of liquid hazardous waste. Most of the acid could be recovered, concentrated, and recycled, thereby reducing the waste stream estimates.

Waste Hardware

The first wall panels, which would provide protection of the target chamber, would require periodic replacement due to wear, damage, and/or chemical contamination. The panels would be replaced every 8 years, resulting in an average estimated waste stream of 1 cubic meter per year of solid LLW waste.

Current design involves a disposable debris-fused silica or glass shield optic concept, which would remotely insert debris shields with a mechanical device somewhat like a compact disc changer. The SSM PEIS did not evaluate this design change. As a result, there would be an increase in the solid LLW as compared to the SSM PEIS. The disposable debris shield optics, which would protect the main debris shields and would be approximately 1-millimeter thick and would be mounted in a plastic frame and held in a cassette holding about 15 debris-shield optics. There would be an ongoing waste stream of solid LLW from the disposable debris shields, estimated at about 59.5 cubic meters per year. Some of the main debris shields would also be disposed of due to damage or other factors, estimated at about 1.9 cubic meters per year.

Other waste hardware associated with the target chamber could be disposed of as solid MLLW because of damage or induced radiation in the material. This waste hardware is estimated to be 0.5 cubic meters per year.

The charge-coupled device cameras used for target chamber diagnostics could be damaged during higher yield experiments and could become a solid LLW stream. There would be as many as 96 cameras used at one time, but they would be small, about 10 cubic centimeters each, and would not increase waste totals significantly.

The total LLW created from these sources would be 63 cubic meters per year, with 0.5 cubic meter per year of MLLW.

High-Efficiency Particulate Air Filters/Pre-filters

There would be two HEPA filters and two pre-filters that would filter radioactive emissions from the target chamber. Approximately 20 additional HEPA filters would filter the air from different areas of the NIF. A change-out schedule of at least once every 10 years would be required by LLNL, unless the HEPA system contains in-line sprinklers (the NIF would not). The LLW waste stream for HEPA filter replacement would be 0.23 cubic meter per year, based on the replacement of the HEPA filters and pre-filters every 10 years. There would be many more HEPA filters in the buildings that would provide clean-room air. These HEPA filters would be contaminated with ambient air contaminants only and would not be a hazardous waste or LLW. The clean-room HEPA filters would not be subject to the change-out schedule discussed above, because their function would not be the protection of persons or the environment.

Waste Oils and Associated Equipment

Vacuum pumps are used to draw a vacuum on the target chamber. An estimate of 0.2 cubic meters per year of mixed liquid oil waste was used in the SSM PEIS for vacuum pump operations. By the time of the 1998 NIF Pollution Prevention Plan (LLNL 1998h), it was believed that oil-free pumps could be used, and that this waste stream could be eliminated. At this time, it is anticipated that vacuum pumps would be used that have oil isolated in the pump transmission casing, so there would be no oil back streaming. The oil must be changed periodically as part of normal maintenance. The oil from the vacuum pumps that are not close to the target chamber could be regulated as hazardous waste. There is still some uncertainty about the volume of waste oil; estimates range from 0.002 to 0.4 cubic meters per year; therefore, the 0.2-cubic-meter value from the SSM PEIS was retained as a reasonable estimate. Waste bearings from the pumps and other spent materials are estimated at 0.06 cubic meters per year of LLW.

M.5.2.13.3.2 *Hazardous Waste*

Waste Oils and Associated Equipment

Oil-filled capacitors would be filled with castor oil. As part of disposal, the castor oil would be drained from the metal frame of the spent capacitor. This waste stream, including the stabilized oil, is estimated to be 7.5 cubic meters per year of hazardous solid. The waste castor oil is usually not a hazardous waste and, under current regulations, could be recycled at an offsite facility. Also, the remaining metal parts of the capacitors could be recycled at an offsite facility to recover the metal content. Therefore, it is possible that this waste stream could be eliminated by recycling. There is some uncertainty, however, whether the oil chemistry could change over time, future regulations could change and affect the management of this waste stream, or the availability of suitable recycling facilities could change. Therefore, a conservative approach was taken for this analysis, and recycling was not assumed.

General Chemicals

Activities in the optics assembly building and laser and target area building would generate some hazardous waste, although there would be pollution prevention techniques in place to eliminate hazardous wastes. The optics assembly building would have two state-of-the-art precision cleaners that would use a nonhazardous aqueous solution for cleaning. The wastewater from these precision cleaners would be sewerable; therefore, this wastewater is included in the sewage wastewater total in Section M.5.2.12. The optics assembly building also would use steam cleaning for general cleaning of surfaces, which also would result in a sewerable discharge.

There would be some metal treating processes, such as passivation of steel, which could result in hazardous acidic or alkaline wastewater.

The mechanical equipment in the optics assembly building and laser and target area building, such as cranes, hoists, and transporters, would require periodic maintenance. The maintenance would generate some petroleum-contaminated wastes, which could be managed as hazardous waste. Maintenance work with paints, coatings, sealants, and adhesives could also contribute to hazardous wastes. This waste stream is estimated at 4.6 cubic meters per year for the optics assembly building and laser and target area building.

M.5.2.14 *Occupational Protection and Human Health*

M.5.2.14.1 *Radiological Exposure*

Personnel would be exposed to two sources of prompt radiation during the NIF yield operations: direct radiation and skyshine radiation. First, personnel located within or very close to the facility would be exposed to some quantity of direct radiation. Direct radiation would consist of both neutrons and gamma rays that would be produced as the neutrons scatter and penetrate through the concrete shield wall and other materials. Second, the neutrons penetrating the facility walls will scatter off of the atmosphere. Personnel throughout the Livermore Site would be exposed to some level of this skyshine radiation. The NIF shielding is designed to reduce the levels of direct and skyshine radiation exposure.

The skyshine dose at an air-ground interface as a function of distance from the center of the cylindrical target bay was calculated using 3-D Monte Carlo analysis. The 1.37-meter-thick concrete target bay roof would limit the skyshine dose at the nearest site boundary, 350 meters due east of the target bay, to less than 0.2 millirem per year for all possible target illumination configurations (Table M.5.2.14.1–1). This was added to the airborne MEI exposure of 0.04 millirems per year to give a total MEI exposure of 0.24 millirems per year.

Personnel within the NIF would also receive a direct dose. Operations personnel, located in the main control room, would receive a direct dose of approximately 5 millirems per year. Those in the diagnostics building would receive about 3 millirems per year, and those in the optics assembly building would receive approximately 1 millirem per year. These direct doses are based upon a 40-hour workweek.

Finally, non-involved workers moving past the target chamber end of the NIF would receive a direct dose of approximately 1 millirem per year, assuming an occupancy of 30 minutes for walkways and roads, as recommended by the National Council on Radiation Protection (NCRP 1993).

The NIF target bay includes about 50 doorways to allow for adequate access of personnel and equipment. To maintain prompt doses at required levels, the entry points would be fitted with steel-enclosed, concrete-shield doors. The doors would range from 0.31 meter to 1.83 meters thick, depending upon their elevation relative to the target chamber and the room to which they lead. Prompt doses immediately outside shield doors in potentially occupied areas would be less than 30 millirems per year.

TABLE M.5.2.14.1–1.—*Radiological Impacts to Public and Workers from Normal Operations (No Action Alternative)*

Receptor	No Action Alternative		SSM PEIS	
	Dose	Latent Cancer Fatality Risk	Dose	Latent Cancer Fatality Risk
Public (site-wide MEI)	0.24 mrem/yr	1.4×10^{-7}	0.1 mrem/yr	6.0×10^{-8}
Population	0.26 person-rem/yr	1.6×10^{-4}	0.2 person-rem/yr	1.2×10^{-4}
Involved workers	<15 person-rem/yr	0 cancers in population (calculated value = 9×10^{-3})	<10 person-rem/yr	0 cancers in population (calculated value = 6×10^{-5})
Noninvolved worker [a]	1 mrem/yr	6×10^{-7}/yr of exposure	0.2 person-rem/yr	1.2×10^{-4}/yr of exposure

Source: LLNL 2003d.

[a] The SSM PEIS presented the dose for the NIF workers and non-NIF workers as a group instead of individuals as analyzed in this appendix. While the number of the NIF workers used in the analysis was not apparent, the SSM PEIS used 330 persons as the employment for the NIF operations. It is unknown how many workers were considered Non-NIF" workers.

MEI = maximally exposed individual; mrem/yr = millirems per year; SSM PEIS = Stockpile Stewardship and Management Programmatic Environmental Impact Statement.

During high-yield operations, tasks that must be performed within the NIF target bay or that involve handling of materials that have been inside the target bay during high-yield experiments would result in some level of radiation dose. Dose rates within the target bay would be dominated by the yield of the most recent experiment. The residual radiation intensity within the NIF target bay at any particular location would depend upon local and general activation in the room as well as the history of yield experiments. The highest intensity would be inside the 10-centimeter-thick, 5-meter-radius, aluminum-alloy target chamber. At early times following a yield experiment, magnesium-27 (half-life = 9.5 minutes) and manganese-56 (2.6 hours) would dominate the residual dose rate. At times of 6 hours to 10 days after yield experiments, sodium-24 (15 hours) would dominate. After decay times of more than 10 days, manganese-54 (312 days), cobalt-60 (5.3 years), and zinc-65 (244 days) would dominate. Occupational doses would be monitored, and maintenance activities and procedures would be organized to minimize occupational doses. Cost-benefit analyses would be performed and auxiliary shielding would be used to ensure that worker doses are kept as low as reasonably achievable.

In addition, a worker dose would be incurred during routine decontamination activities. This would include handling of contaminated/activated items, disassembling them (if needed), and processing them through the decontamination systems.

NIF annual worker exposure goals would include:

- Less than 500 millirems per year individual worker dose
- Less than 15 person-rems per year cumulative worker dose

Physical features, such as confinement, ventilation, tritium processing system, shielding, and an elevated release point would be used as supplemental methods to control radiation exposure. A *Measurement and Retrofit Plan* has been written to identify key locations in which prompt and residual doses would be measured and facility additions and/or modifications that could be made if measurements suggest that radiation protection calculations underestimated those doses (LLNL/NIF 1997b). An *Auxiliary Shielding Plan* has been written to identify potential uses for temporary neutron and gamma-ray shielding (LLNL/NIF 1997a). Such shielding could prove beneficial in reducing worker doses to as low as reasonably achievable (ALARA) levels.

The dose at the site boundary would be dominated by neutron skyshine; direct dose would be small by comparison. Such doses are not covered by NESHAP, but are limited by DOE O 5400.5, "Radiation Protection of the Public and the Environment." This order limits doses caused by all pathways of release of radiation or radioactive material to 100 millirems per year effective dose equivalent for prolonged exposure and 500 millirems per year effective dose equivalent for occasional exposure (DOE 1993a).

The NIF MEI dose from airborne effluent releases would be 0.04 millirem per year (Section M.5.2.8.4). When added to the 0.2-millirem-per-year dose from the skyshine, the total MEI dose from the NIF operations under the No Action Alternative would be 0.24 millirem per year. This dose is less than 0.3 percent of the DOE standard and would result in an increase in annual latent cancer fatality risk of 1.2×10^{-7}. The skyshine would not result in any increase in the overall population dose because the exposure to the skyshine would be limited to close proximity to LLNL boundary next to the NIF.

M.5.2.14.2 *Nonradiological Exposure*

Potential nonradiological impacts to human health and safety posed by the NIF operations under the No Action Alternative would include chemical exposure pathways and risks of occupational injuries, illnesses, and fatalities resulting from normal (accident-free) operations, and potential laser exposure. Involved and uninvolved workers could be affected.

Operations at the NIF would involve a range of activities that would pose the potential for exposures of hazardous materials or conditions to the NIF workers and other LLNL workers. These hazards would include chemical and industrial hazards. Evaluation of occupational protection issues considers existing LLNL programs that specifically address worker and general population protection measures implemented to control, reduce, or eliminate operational hazards. Appendix C of LLNL SW/SPEIS presents a detailed description of LLNL Environment, Safety, and Health (ES&H) programs implemented to monitor and ensure that all sectors of the local environment are protected.

It is the policy of NNSA and LLNL to operate the Laboratory in a manner that protects the health and safety of employees and the public, preserves the quality of the environment, and prevents property damage. ES&H is to be a priority consideration in the planning and execution of all work activities at LLNL. It is also the policy of LLNL to comply with applicable ES&H laws, regulations, and requirements; and with directives promulgated by DOE regarding occupational safety and health, as adopted in LLNL Work Smart Standards set. ES&H functional organizations provide assistance and direction in implementing worker, environmental, and public safety programs to assure that all regulatory requirements are met.

Some nonradiological hazardous materials would be present at the NIF. Occasional nonroutine air emissions of these types of materials would be expected from operation of electrical equipment, wipe cleaning, and occasional use or maintenance/testing of the standby generators.

The potential exists for personnel exposures to beryllium resulting from the NIF operations. Beryllium containing targets would contribute to airborne and surface contamination. This contamination would be contained within the NIF target chamber. Personnel exposures to these contaminants would be controlled through the implementation of ES&H requirements, specifically Document 14.4, *Implementation of the Chronic Beryllium Disease Prevention Program Requirements* (LLNL 2001ad). Personnel monitoring and area decontamination practices would be employed to reduce the contamination source term and to minimize hazards to facility workers.

The use of the chemicals under the No Action Alternative (see Section M.5.2.13.2) would not necessarily result in additional worker exposures. Continued application of site ES&H and Integrated Safety Management System principles would result in minimal impacts to worker and the public. Thus no adverse impacts from this action would be expected.

M.5.2.14.3 *Physical Hazards*

The NIF would use a powerful laser. Powerful lasers are hazardous to the eyes and skin, whether exposure is to the direct beam of the laser or reflections. At the NIF, laser safety would be particularly important. Laser safety officers would ensure that lasers are operated according to LLNL safety procedures, which are based on integrated safety management techniques. These management techniques would include controlling access to the laser operational area and requiring use of safety interlocks, warning systems and signs, remote operation, and eye protection.

Physical hazards, such as noise, electrical shock, and workplace injuries/illnesses, would exist under the No Action Alternative, but workplace injury/illness statistics show a decreasing trend over the past 10 years.

M.5.3 Proposed Action

The Proposed Action would involve the proposed use of plutonium; other fissile materials, materials that fission when irradiated by slow or thermal neutrons such as small quantities of special nuclear material, uranium-235; fissionable materials, materials that can be induced to fission by fast neutrons such as uranium-238 (depleted uranium) or thorium-232; and lithium hydride/deuteride in experiments on the NIF. The specific fissile/fissionable materials, beyond depleted uranium, considered for the Proposed Action would be weapons-grade plutonium, highly enriched uranium, and thorium-232. Yield experiments and non-yield experiments with highly enriched uranium, thorium-232, small quantities of specially prepared plutonium, and other fissionable materials would be performed at the NIF target chamber without additional containment. Most special nuclear material experiments would be performed using an additional sealed inner containment vessel to protect the target chamber.

It is estimated that there would be a maximum of four yield experiments with an inner containment vessel per year, at maximum fusion yields up to 45 megajoules, and 10 nonyield experiments with an inner containment vessel with plutonium per year. Other highly radioactive actinides, whose use is not currently envisioned, would also require the use of the inner containment vessel. If used, the inventories of these materials would be limited such that their environmental impact (offsite accidents, worker exposure, etc.) would not exceed the bounds defined in this document. Other materials that would also be used under the Proposed Action at the NIF would be increased quantities of depleted uranium, beryllium, and lithium hydride/deuteride.

In addition, the Proposed Action would include the construction and operation of a neutron spectrometer. Construction and operation of a neutron spectrometer is proposed to more accurately measure neutron yield and diagnose ignition target physics.

M.5.3.1 *Land Use and Applicable Plans*

The generalized land use at LLNL and vicinity is zoned for industrial park use. The industrial land use for the NIF would be the same as outlined under the No Action Alternative. The NIF land use would be compatible with LLNL land use. The construction of the neutron spectrometer would be consistent with the NIF land use. The Proposed Action would not result in any change to the land use for the immediate area of the NIF or land use in the overall vicinity. No impacts to land use would be expected under the Proposed Action.

M.5.3.2 *Socioeconomic Characteristics and Environmental Justice*

M.5.3.2.1 *Socioeconomics*

The Proposed Action would include the potential addition of a neutron spectrometer. The construction of the neutron spectrometer would result in the temporary employment of 20 workers.

Under the Proposed Action, the NIF would be operated as evaluated in the No Action Alternative plus the operations associated with experiments containing additional materials. Current projections for the Proposed Action are that 186 employees would be needed for direct operations along with 240 support personnel. Together, 426 long-term workers would be employed at the NIF and its support operations. This is an increase of 26 new hires over the employment level under the No Action Alternative. Most of these workers are already employed at LLNL, either working on making the NIF operational or at other LLNL facilities. Any new hires would fall within the 5- to 8-percent annual turnover at LLNL. Therefore, no impacts to local housing, schools, or medical services would be anticipated.

M.5.3.2.2 *Environmental Justice*

The impacts associated with the operation of the NIF with potential for disproportionate effects would be radioactive air emissions. These impacts would be negligible beyond a 5-mile radius (see Section M.5.3.8). Therefore, there would be no disproportionately high and adverse impacts to minority or low-income populations under the Proposed Action.

M.5.3.3 *Community Services*

The existing LLNL fire protection and emergency services, police protection, and security services would not change under the Proposed Action. The level of services provided currently and during the construction of the NIF would not change. Because there would be no substantial change in the workforce, there would be no changes in the socioeconomic impacts and no associated change in school services.

The NIF is generating and would continue to generate waste office paper, cardboard, plastic, sanitary wastes, and other nonhazardous refuse at a rate similar to LLNL as a whole. There would be nothing unique about the refuse generation from the NIF, in terms of waste types or amounts; therefore, this type of waste is projected on a per capita basis. As a conservative estimate, it is assumed that each worker would generate one cubic meter of nonhazardous solid waste. With a projected total of 426 long-term workers at the NIF and its support operations, the projected amount of nonhazardous solid waste would be 426 cubic meters per year. This would be an increase of 26 cubic meters, or 6.5 percent, over the amount of nonhazardous solid waste generated under the No Action Alternative. Because 380 long-term personnel are already employed at NIF, it would take 46 new personnel to meet the projected employment level under the Proposed Action. These new hires would represent an associated increase of 46 cubic meters of nonhazardous solid waste over the amount of waste that is already part of the overall LLNL waste figures. This amount represents a 1 percent increase in the site's current generation of nonhazardous waste; therefore, no impacts would be expected to the capacity to handle nonhazardous solid waste under the Proposed Action.

M.5.3.4 *Prehistoric and Historic Cultural Resources*

No prehistoric archaeological resources have been identified on or near the NIF site. No buildings and facilities at LLNL that may have potential to be eligible to the National Register of Historic Places are located near the NIF. Because much of the NIF site has been developed, the likelihood of finding unrecorded and undisturbed prehistoric sites is low. There is the possibility that undisturbed sites lay buried under the modern landscape. Under the Proposed Action, the potential construction of the neutron spectrometer would involve excavation. A small potential exists for sites to be encountered during excavation and other site activities. Should any buried materials be encountered, LLNL would evaluate the materials and proceed with recovery in accordance with cultural requirements and agreements. Operation of the NIF, as described in the Proposed Action, would not impact any prehistoric or historic cultural resources.

M.5.3.5 *Aesthetics and Scenic Resources*

The NIF conventional facility construction is now complete. All conventional facilities are constructed and turned over for equipment installation. No further changes to the visual features would occur in the area of the NIF. The only potential new construction, the neutron spectrometer, would be entirely underground with an outside stairwell for access. There would be no impacts to aesthetic and scenic resources under the Proposed Action.

M.5.3.6 *Geologic Resources*

The Proposed Action includes the potential addition of a neutron spectrometer. The construction of the neutron spectrometer would result in excavation within a 3,400-square-foot area to a maximum depth of 52 feet (up to 176,000 cubic feet in volume). The area to be excavated would be adjacent to the southwest side of the NIF. Because this area has been disturbed during the construction of the NIF, no further impacts to soils would result under the Proposed Action. Aggregate and other geologic resources, such as sand, would be required to support the construction of the neutron spectrometer, but these resources are abundant in Alameda County.

The potential exists for fossils, contaminated soils, and other media to be encountered during excavation. During construction of the NIF, mammoth bones, including a jawbone, partial skull, tusks, and some vertebrae, were found. The area was surveyed at the time and no sign of additional fossils was noted. LLNL would sample the area to be excavated before any digging. Should any buried materials be encountered, LLNL would evaluate the materials and proceed with recovery in accordance with appropriate requirements and agreements.

M.5.3.7 *Ecology*

The Proposed Action includes the potential addition of a neutron spectrometer. The construction of the neutron spectrometer would result in the disturbance of an area of 3,400 square feet. The area to be excavated would be adjacent to the southwest side of the NIF. Because this area has been disturbed during the construction of the NIF and excavation would occur within the existing stormwater control area, no further impacts to biological resources would result from the construction associated with the Proposed Action. No impacts would occur to the nearby wetland area. Few impacts would occur to biological resources during operation of the NIF. The traffic to and from the NIF would have associated animal road kill occurrences. No adverse impacts to threatened and endangered species or species of special concern would be expected from operation of the NIF.

M.5.3.8 *Air Quality*

During normal operations, some experiments at the NIF would result in atmospheric releases of small quantities of tritium, some radionuclides produced by activation of gases in the target bay air, and, in the case of the Proposed Action, small quantities of fission product gases.

Some nonradiological hazardous materials would be present at the NIF. Routine emissions of these types of materials would be expected from operation of electrical equipment, wipe cleaning, and occasional use or maintenance testing of the standby generators. The projected air pollutant emission rates associated with increased fuel combustion in boilers and engines, and the increased vehicular activity associated with increased workforce at LLNL under the LLNL SW/SPEIS No Action Alternative, which would include the NIF, are provided in Table 5.2.8.1–3 of the main LLNL SW/SPEIS text. The total emissions would be a small fraction of project significance levels and threshold levels for conformity.

M.5.3.8.1 *Criteria Air Pollutants*

The emission of criteria air pollutants that would result from normal operations of the NIF under the Proposed Action are equivalent to those that would be expected from normal operations under the No Action Alternative. The criteria air pollutants emissions would occur primarily from solvent cleaning and fuel combustion. These activities would be the same under the Proposed Action as under the No Action Alternative.

M.5.3.8.2 *Hazardous Air Pollutants*

LLNL evaluates a list of approximately 200 compounds to confirm applicability under the NESHAP. Emissions of hazardous air pollutants for all of LLNL would be less than one-half of the threshold of 7 tons per year for a single hazardous air pollutant or 15 tons per year for a combination of hazardous air pollutants (LLNL 2002ae). The normal operations of the NIF under the Proposed Action would not result in the emission of hazardous air pollutants, except for possible beryllium emissions at very low levels.

M.5.3.8.3 *Toxic Air Emissions*

Under the Proposed Action, the toxic air emissions at the NIF would not increase substantially above that associated with the No Action Alternative. An additional 18.4 grams of beryllium would be used; however, extremely small emissions would be expected well below the toxic air contaminant threshold.

No increase in impacts from LLNL hazardous air pollutants would occur under the Proposed Action. There would be an increase in the very small emissions of beryllium. This small increase would have negligible impacts. The increase in the emission of VOCs would be bounded at 15 percent. The impacts of the increase would be minor.

M.5.3.8.4 *Radiological Air Quality*

Under the Proposed Action, releases of activated target bay gas would be the same as presented for the No Action Alternative in Section M.5.3.8.4. The air in the target bay and the yield of the experiments would be the same as under the No Action Alternative.

Under the Proposed Action, fission products would be created during nonplutonium experiments with yield involving fissile or fissionable materials, and some would be routinely released to the environment as part of normal operations. For yield experiments with plutonium, fission products would be contained within the inner containment vessel. Some longer-lived gases would remain when the vessel is opened to retrieve debris for analysis. These, along with remaining semivolatile fission products, once scrubbed through the radioactive confinement system, would be released to the environment from the Tritium Facility. There would be a maximum of four yield experiments with plutonium per year, at fusion yields up to 45 megajoules.[7]

The fission product inventories created in the target chamber from plutonium experiment neutron activation would be bounded by the highly enriched uranium fission products routinely released and listed in Table M.5.3.8.4–1. Many of these fission products are short-lived, and would decay while being held on the cryopumps or in the accumulation tank. Some long-lived gaseous fission products, such as krypton-85 (10.7-year half-life), would likely be released to the environment. Other semivolatile fission products; e.g., iodine isotopes, would be captured on charcoal filters, which would be at least 99 percent efficient, thus minimizing any release of these radionuclides to the environment. For the purpose of this analysis, a conservative efficiency of 95 percent has been assumed for the filters. Therefore, 5 percent of the mobilizable iodine isotopes could be released.

Table M.5.3.8.4–1 lists the maximum annual quantities of fission products expected to be produced and released under the Proposed Action. These emissions would be in addition to the releases of activated target bay gases listed under the No Action Alternative. The quantities represent the inventories that would result from a 1,200-megajoule annual yield and that would be uniformly released to the environment over one year. Possible sources of these additional fission product emissions are provided: highly enriched uranium, depleted uranium, and thorium-232, with highly enriched uranium as the limiting case for comparable masses.

Table M.5.3.8.4–2 presents the potential impacts of radiation exposures from normal operations to the public. The doses to involved workers would be due, primarily, to radiation exposure from activated structures and components (see Section M.5.3.14.1). The impacts under the No Action Alternative are presented for comparison.

[7] There would also be up to 10 nonyield experiments per year, but these would not contribute to any additional routine radioactive airborne emissions.

TABLE M.5.3.8.4–1.—*Annual Routine Radioactive Airborne Emissions under the Proposed Action (Fission Products)*

Nuclide	Annual Amount Available for Release (Ci/1,200 MJ)[b]	Annual Air Effluents Via Charcoal Filter[a] (Ci/1,200 MJ)
Krypton-83m	1.1×10^{-13}	1.1×10^{-13}
Krypton-85	3.5×10^{-4}	3.5×10^{-4}
Krypton-85m	2.9×10^{-7}	2.9×10^{-7}
Krypton-87	0	0
Krypton-88	2.3×10^{-11}	2.3×10^{-11}
Krypton-89	0	0
Iodine-131	1.9	9.3×10^{-1}
Iodine-132	3.9	1.9×10^{-1}
Iodine-132m	0	0
Iodine-133	1.1	5.6×10^{-2}
Iodine-133m	0	0
Iodine-134	0	0
Iodine-134m	0	0
Iodine-135	6.1×10^{-4}	2.8×10^{-5}
Iodine-136	0	0
Xenon-131	6.1×10^{-3}	6.1×10^{-3}
Xenon-133	5.9	5.9
Xenon-133m	2.1×10^{-1}	2.1×10^{-1}
Xenon-134m	0	0
Xenon-135	4.5×10^{-2}	4.5×10^{-2}
Xenon-135m	9.0×10^{-5}	9.0×10^{-5}
Xenon-137	0	0
Total	1.3×10^{1}	6.5

Source: LLNL 2003d.
[a] The effluents from the cryopumps during regeneration and from the target chamber when bringing to air would be passed through 2-inch-thick charcoal filters to remove iodines, with 99 percent being collected by charcoal bed. Here, only 95 percent is assumed removed for conservatism.
[b] 1.2 gram uranium-235/target: 2×10^{16} Fissions per 1,200-MJ experiment, 60 experiments per year.
Ci = curies; MJ=megajoules.

TABLE M.5.3.8.4–2.—*Radiological Impacts to the General Public from Airborne Effluent Emissions during Normal Operations (Proposed Action)*

Receptor	Proposed Action		No Action Alternative	
	Dose	Latent Cancer Fatality Risk	Dose	Latent Cancer Fatality Risk
NIF Offsite MEI	0.07 mrem/yr	4.2×10^{-8} /yr of exposure	0.04 mrem/yr	2.4×10^{-8} /yr of exposure
Population Dose	0.29 person-rem/yr	1.7×10^{-4}	0.26 person-rem/yr	1.6×10^{-4}

Source: LLNL 2003d.
MEI = maximally exposed individual; mrem = millirems; yr = year; NIF = National Ignition Facility.

The baseline dose to the MEI from Livermore Site operations (site-wide MEI) without the NIF operations would be 0.017 millirem per year with an associated population dose of 0.16 person-rem per year (SNL 2000). Due to proposed increases in Building 331 tritium releases, the LLNL SW/SPEIS Proposed Action dose to the site-wide MEI without the NIF operations would be 0.058 millirem per year. The location of the site-wide MEI would correspond with the NIF MEI location. Conservatively adding the site-wide MEI Proposed Action dose (0.058 millirem per year) to the NIF MEI dose for airborne effluent emissions (0.068 millirem per year) results in an estimated dose of 0.126 millirem per year for airborne effluent emissions under the NIF Proposed Action. This dose would be less than 2 percent of the NESHAP limit. The component of population dose from routine of the NIF releases would be 0.29 person-rem per year. Adding this dose to LLNL SW/SPEIS Proposed Action population dose of 1.55 person-rem per year would result in a dose of 1.84 person-rem per year. This population dose would be many orders of magnitude less than the dose received from natural background. No adverse impacts on radiological air quality are expected from the Proposed Action.

M.5.3.9 *Water*

The NIF conventional facility construction is now complete. The Proposed Action includes the potential addition of a neutron spectrometer. The construction of the neutron spectrometer would result in excavation to a depth of 52 feet. This depth is close to the level the water table reaches in rainy seasons. Best management practices would be implemented to control stormwater and sediment runoff during construction. Potential impacts to water resources would be similar to those described in Section 5.3.9 of this LLNL SW/SPEIS.

The neutron spectrometer is a detection device that does not impart any radioactivity of its own to the soils or groundwater. The neutron spectrometer could use 1 cubic meter of a plastic scintillator material in a concrete shaft, with a geomembrane underneath to prevent any contamination of the groundwater during operation.

Under the Proposed Action, water usage at the NIF would be the same as under the No Action Alternative, currently expected to be 27.6 million liters per year or approximately a 3.5 percent increase in LLNL usage of 795 million liters per year in 2001. Because no expansion of capacity would be required, there would be no impacts associated with expansion of capacity. The impacts of the increase in water use would be negligible in nondrought years. During drought years, the impacts of this increase in water use at LLNL would be of concern.

M.5.3.10 *Noise*

There would be minor temporary construction noise associated with the construction of the neutron spectrometer.

The noise level under the Proposed Action would be the same as for the No Action Alternative, similar to an industrial facility (approximately 85 decibels). The noise at the NIF would be equal to other local industrial/commercial activities. The contribution of these activities to offsite noise levels offsite is small. The impulse noise resulting from the NIF experiments would primarily come from the triggering of the capacitors. The noise would be heard outside the NIF building for a short distance only. This noise is would be momentary and intermittent, occurring only at the time of an experiment, up to 6 times per day. No offsite noise would result from the experiments. The impacts of noise to workers would be normal for industrial facilities. With standard hearing protection, no impacts from noise would be expected. No impacts would be expected from noise to the public.

M.5.3.11 *Traffic and Transportation*

Traffic

The construction of the NIF conventional facilities is completed. As a result, the traffic associated with the construction workers has ceased. The pre-operational and operational workforces are already employed onsite. The construction of the neutron spectrometer would result in the temporary employment of 20 workers and some temporary material transportation. Any new employees for operation of the NIF under the Proposed Action would fall within the 5- to 8-percent annual turnover at LLNL. Therefore, there would be no substantial change in the amount of traffic that currently exists.

Radiological Transportation

Routine onsite transportation of targets would have no impact to the public, as access to LLNL is restricted. The onsite transportation would fall within the scope of operational activities already analyzed for the site and the NIF in particular.

Under the Proposed Action, radioactive materials would be transported to LLNL from Los Alamos National Laboratory for NIF targets. These materials would include 10 shipments per year, each with 6 grams of plutonium; 10 shipments per year, each with 3 grams of highly enriched uranium; 10 shipments per year, each with 5 grams of depleted uranium; and 15 shipments per year, each with 100 curies of tritium.

For incident-free, i.e., no accidents, transport; of plutonium, highly enriched uranium, and depleted uranium, the consequences would be the radiation dose potentially received by the truck drivers and members of the public driving on the highways, living near the highways, and present at rest stops. Because of the very small amounts of radioactive material being transported and the shielding of the containers and vehicle, the radiation dose rate near the truck would be immeasurably small. Therefore, there would be no incident-free radiation dose to drivers or members of the public.

Tritium does not produce an external dose rate. Therefore, transport of tritium would also have no incident-free radiological impacts. Section M.5.6 presents the consequences of transportation accidents, which includes tritium transport accidents.

Transportation of Plutonium Targets and Inner Containment Chamber

An inner containment vessel for experiments with plutonium would be loaded and brought from the Superblock and transported to the NIF as a sealed and assembled unit. The vessel would be transported in a shipping container. Once the test is complete, the inner chamber would be removed, placed in a shipping container and returned to the Superblock for post-test examination and processing. The inner chamber, having been used in a single test, would then be dismantled, if appropriate; placed in a shipping container; and transported to the Nevada Test Site for disposal as LLW.

M.5.3.12 *Utilities and Energy*

The utility usage at the NIF would be dominated by the operations of the facility at clean-room conditions. Changes in the number and type of experiments would not change the overall utility usage. Under the Proposed Action, the utility usage would be the same as that discussed under the No Action Alternative.

M.5.3.13 *Materials and Waste Management*

NIF research activities would use a variety of hazardous (radioactive and toxic) and nonhazardous materials. No explosive materials would be used at the NIF. All of these would become part of material management for the NIF. The primary strategy for the control and management of hazardous materials at the NIF would be to minimize exposures to hazardous substances in accordance with regulatory requirements, institutional goals, and best management practices. Once the materials have been used, they would be classified and managed under the NIF's and LLNL's waste management procedures. Waste management is discussed in Section M.5.3.13.3. During the use and management of these materials, air emissions would occur. Emissions were discussed in Section M.5.3.8.

Particulates would be generated in the target chamber from each experiment. The management of the radioactive particulates and tritium is discussed in Section M.5.3.13.1. Nonradiological materials are discussed in Section M.5.3.13.2.

M.5.3.13.1 *Radionuclide Materials Management*

The materials contained in targets and the activation of materials in the target bay described under the No Action Alternative would be the same under the Proposed Action. Yield experiments would emit neutrons, energetic particles, debris, and x-rays. Some neutrons would activate the target chamber and target bay air. Under the Proposed Action, there would be the additional use of plutonium, other fissile materials, fissionable materials, and lithium hydride/deuteride in experiments. Most of the unburned tritium would be exhausted to the tritium processing system, while a small amount would be adsorbed onto the target chamber wall and other items contained in the target chamber.

The particulates would be generated in the same manner as described under the No Action Alternative. The particulates created in the target chamber under the Proposed Action, in addition to the No Action Alternative quantities, would include increased amounts of beryllium and depleted uranium as well as lithium hydride/deuteride, plutonium, highly enriched uranium, thorium-232, and other materials used as tracers. Table M.5.3.13.1–1 lists the upper bounds on the amount of materials that would be expected in the target chamber under the Proposed Action. The in-chamber inventories provided in Table M.5.3.13.1–1 are conservative estimates of the amount of material that would be present as particulates at the end of one year.

Particulates created in the target chamber would see neutrons from yield experiments and be subject to neutron activation. Fissile and fissionable isotopes would also be subject to fission. Table M.5.3.13.1–2 lists the prominent nuclides expected to result from neutron exposure of target materials in the target chamber. This includes the gas that could be contained in targets or created during nonplutonium fissile material experiments with yield, such as krypton, xenon, deuterium, and tritium. The gas would be removed through the high-vacuum cryopumps.

As noted earlier, for experiments, radioactive particulates created in the target chamber would be transferred to the decontamination systems and waste streams. However, because many are short-lived species, the maximum inventories associated with particulates would be found in the target chamber shortly after the last experiment and well before cleanup. By the time cleaning occurs or components are removed, the radioactive particulate inventory would have decayed to much smaller quantities. The inventories in Table M.5.3.13.1–2 would be maximum radionuclide inventories under the Proposed Action. This would include the production of activated species and fission products from yield experiments. Experiments correspond to a final 45-megajoule-yield experiment, ending one year of experiments with 1,200- megajoules total yield.

For most plutonium experiments, an inner containment vessel would be used. The inventory from each yield experiment with plutonium would remain inside its inner containment vessel. Consequently, the inventory for the yield experiment case would not contribute to the inventory that builds up in the target chamber. Each inner containment vessel would only be used for a single experiment. These inventories would include 3 grams of weapons-grade plutonium for the nonyield experiments. For yield experiments, the inventory would include 1 gram of plutonium, associated fission products, and activated particulates resulting from a single 45-megajoule experiment. After retrieving any debris for analysis from inside the inner containment vessel (performed in the Tritium Facility), the inner containment vessel and remaining contents would enter the waste stream.

The inventories presented in Table M.5.3.13.1–2 represent the maximum inventories for each type of experiment: depleted uranium plus fission products, highly enriched uranium plus fission products, thorium-232 plus fission products, weapons-grade plutonium (3 grams), weapons-grade plutonium (1 gram) plus fission products, or tracer activation products, calculated as if each type was present during a last 45-megajoule experiment just before the annual cleanup. While each experiment could not be the last experiment, the inventories from the other experiments would have more time to decay. However, because there is no way to predict which type of experiment would be the last, the maximum inventory of each type is used to set the radiological bound.

TABLE M.5.3.13.1–2.—*Estimated Maximum Mobilizable Radionuclide Inventories (Proposed Action) (continued)*

Isotope	Quantity (Ci)

Source: LLNL 2003d.

[a] Depleted uranium is already slightly radioactive; the half-life of uranium-238 (dominant isotope) is 4.5×10^9 yrs. The assumed composition would be 99.64% uranium-238, 0.36% uranium-235, and 0.0028% uranium-234. The quantities listed correspond to the maximum quantity that would be used under the Proposed Action of 100 g. Fission products would result from a single target (maximum of 2.2 g) subject to 45-MJ fusion yield (4.6×10^{16} fissions) and would include residual fission products from previous yield experiments (60 @ 20 MJ). The fission product inventories provided would be peak post-experiment inventories.

[b] HEU is already slightly radioactive; the half-life of uranium-235 (dominant isotope) is 7.0×10^8 yrs). The assumed composition would be 93.5 wt% uranium-235, 5.4 % uranium-238, and 1.1 % uranium-234. The quantity listed corresponds to the maximum quantity that would be used under the Proposed Action of 100 g. Fission products would result from a single target (maximum of 1.2 g) subject to a 45MJ fusion yield (4.6×10^{16} fissions) and would include residual fission products from previous yield experiments (60 @ 20 MJ). The fission product inventories provided would be peak post-experiment inventories.

[c] Thorium-232 is already slightly radioactive, with a half-life of 1.4×10^{10} yrs). The quantity listed corresponds to the maximum quantity that would be used under the Proposed Action of 450 g. Fission products would result from a single target (maximum of 7.9 g) subject to a 45-MJ fusion yield (5.3×10^{16} fissions) and would include residual fission products from previous yield experiments (60 @ 20 MJ). The fission product inventories provided would be peak post-experiment inventories.

[d] The assumed composition of weapons-grade material would be 0.02% plutonium-238, 93.85% plutonium-239, 5.8% plutonium-240, 0.3% plutonium-241, 0.015% americium-241, and 0.02% plutonium-242. Other isotopic mixes could be used as long as their impacts are within the bounds described here. The fission products would result from a single target (maximum of 1 g) subject to a 45-MJ fusion yield (3.2×10^{16} fissions). Because only a single experiment would occur within an inner containment vessel, only the fission products resulting from this single experiment would be included. The fission product inventories would be peak post-experiment inventories.

[e] Bounds the use of small quantities of specially prepared plutonium.

Ci = curies; g = grams; MJ = megajoules; wt% = percent by weight.

Plutonium Experiment Containment Vessel

For most tests with plutonium[8], an inner containment vessel, presently assumed to be fabricated from stainless steel, would be used to prevent the weapons-grade plutonium[9] and associated fission products from being deposited on the main NIF target chamber, first wall, target positioner, or diagnostics. This inner containment vessel would be brought from the Tritium Facility as a sealed and assembled unit. The vessel would be placed into the target chamber through the large port at the waist of the target chamber or through the bottom of the NIF target chamber. The inner containment vessel would be positioned so that the target would be placed at the target chamber center and the experiment performed using all or a subset of the laser beams. Once the experiment is complete, the inner containment vessel would be returned to the Tritium Facility for post-experiment examination and processing.

Depleted Uranium

Depleted uranium would arrive at the facility in individual targets, each with up to 2.2 grams of depleted uranium. The maximum annual depleted uranium throughput at the NIF under the Proposed Action would be limited to 100 grams. Depleted uranium is slightly radioactive; the half-life of uranium-238 [(dominant isotope]) is 4.5×10^9 years). Depleted uranium is also considered to have toxic properties.

[8] If other fissile materials were required for NIF experiments, the inventories of these materials would be limited such that their environmental impact (offsite accidents, worker exposure, etc.) would not exceed the bounds defined in this document.

[9] The assumed composition of weapons-grade material would be 0.02% plutonium-238, 93.85% plutonium-239, 5.8% plutonium-240, 0.3% plutonium-241, 0.015% americium-241, and 0.02% plutonium-242. Other isotopic mixes could be used as long as their impacts are within the bounds described here.

Tritium

Under the Proposed Action, tritium would be handled and used in the same manner as under the No Action Alternative.

Fission Products

Fission products would be created during yield experiments involving fissile or fissionable materials. The fission product inventories would be bounded by the highly enriched uranium fission products that would be routinely released, which are listed in Table M.5.3.8.4–1. For yield experiments with plutonium, fission products would be contained within the inner containment vessel. Some longer-lived gases would remain when the vessel is opened to retrieve debris for analysis. Once scrubbed through the radioactive confinement system, these gases, along with remaining semi volatile fission products, would be released from the Tritium Facility to the environment.

M.5.3.13.2 *Nonradiological Materials Management*

The management of nonradiological materials would be essentially the same as for the No Action Alternative. Waste is discussed in Section M.5.3.13.3.

Nonradiological Particulates

The nonradiological particulates that would be generated under the Proposed Action, in addition to those generated under the No Action Alternative (Table M.5.3.13.2–1), would include increased amounts of beryllium, depleted uranium, and lithium hydride. Table M.5.3.13.2–1 provides a summary of the nonradiological particulate inventories estimated under the Proposed Action.

TABLE M.5.3.13.2–1.—*Bounding Annual Nonradiological Particulate Inventories in the Target Chamber (Proposed Action)*

Material	Maximum Inventory (grams)
Beryllium	20
Lithium hydride/deuteride	125
Uranium	100

Source: LLNL 2003d.

The in-chamber inventories provided in Table M.5.3.13.2–1 are conservative estimates; i.e., over-estimates, of the amount of material that would be present as particulates at the end of one year. Target chamber cleaning more than once a year would reduce the inventory.

The use of volatile organic solvents, cleaning agents, mercury in power conditioning units and preamplifier modules, cleaners, oils, and miscellaneous other materials would be the same as under the No Action Alternative.

Chemical Use in Neutron Spectrometer

The main material used in the neutron spectrometer would be 43,000 pounds of lead used as the fixed shielding in the underground chamber. Sheets of polyvinyl toluene would be used as scintillation sources. A total volume of 1 cubic meter of polyvinyl toluene would be used.

Table M.5.3.13.2–2 provides a summary of the nonradiological materials that would be used in the neutron spectrometer.

TABLE M.5.3.13.2–2.—*Estimated Important Chemical Inventories for the Neutron Spectrometer*

Chemical	Source	Quantity	Exposure Criteria[a]
Lead	Shielding for neutron spectrometer	43,000 lbs	150 mg/m^3
Polyvinyl toluene	Scintillation material	1 m^3, 4,000 lbs	Not determined

Source: LLNL 2003d.
lbs = pounds; m^3 = cubic meters; mg/m^3 = milligrams per cubic meter.

M.5.3.13.3 *Waste Management*

The wastes from the NIF operations under the Proposed Action (Table M.5.3.13.3–1) would be substantially the same as those described under the No Action Alternative. Many of the waste streams, such as wastes from tritium processing and mixed waste, would be unchanged for the Proposed Action, as they would not be directly related to the proposed changes in materials used for experiments. The use of the inner containment vessel would involve the generation of additional LLW, primarily from the spent vessels.

TABLE M.5.3.13.3–1.—*National Ignition Facility Waste Estimates for Low-Level, Mixed, and Hazardous Wastes (Annual) under the Proposed Action*

Source of Waste	Low-Level Radioactive		Mixed		Hazardous	
	Solid (m^3)	Liquid (m^3)	Solid (m^3)	Liquid (m^3)	Solid (m^3)	Liquid (m^3)
Tritium processing	3.2	–	0.003	–	–	–
Wipe cleaning	3.3	0.3	1.0		1.0	–
HEPA filters/pre-filters	0.27	–	–	–	–	–
Waste hardware	63	–	0.5	–	–	–
Chemical treatment/decontamination	–	1.3	0.3	4.9		1.5
Waste oils/equipment	0.06	–	–	0.2	7.5	0.2
General chemicals	–	–	–	–	–	4.6
Inner containment vessel	120					
Total/year	190	1.6	1.8	5.1	8.5	6.3
No Action Alternative Total/year	70	1.6	1.8	5.1	8.5	6.3

Source: LLNL 2003d.
HEPA = high efficiency particulate air; m^3 = cubic meters.

M.5.3.13.3.1 *Radioactive and Mixed Waste*

High-Efficiency Particulate Air Filters/Pre-filters

Because fission products could be produced from some yield experiments, it is expected that there would be a small increase (0.04 cubic meters) in LLW related to filters processing the target chamber exhaust. Charcoal filters would be used to capture iodine isotopes, and these would need periodic, although infrequent, replacement. Other waste streams, such as target chamber hardware or decontamination wastes, would not be expected to change since the same cleaning frequency as the No Action Alternative would seem appropriate.

Plutonium Experiment Containment Vessel

For plutonium experiments, disposal of the inner containment vessel would increase the low-level radioactive waste stream. Because the inner containment vessel, in most or all cases, would leave LLNL site after post-experiment processing in the Tritium Facility, this source of waste would appear in the Tritium Facility waste stream. Each inner containment vessel would occupy approximately 8.5 cubic meters of space, including void volume. The solid LLW stream quantity for 10 nonyield and 4 yield experiments would be 120 cubic meters per year. Because the inner containment vessel would be used only once, it would not require treatment and/or decontamination after each experiment. After sample retrieval, the inner containment vessel would be packaged and shipped to the Nevada Test Site for disposal as LLW.

M.5.3.13.3.2 *Hazardous Waste*

The hazardous waste streams from the NIF operations would be the same for the Proposed Action as for the No Action Alternative. The experiments with additional materials would not generate additional hazardous wastes.

M.5.3.14 *Occupational Protection and Human Health*

M.5.3.14.1 *Radiological Exposure*

Personnel would be exposed to two sources of prompt radiation during the NIF yield operations: direct radiation and skyshine radiation. Also, after yield operations, tasks that must be performed within the NIF target bay or that involve handling of materials that have been inside the target bay during yield experiments would result in some level of radiation dose. This would not change from the No Action Alternative.

For most plutonium nonyield and yield experiments, an additional exposure would occur during placement of the inner containment vessel into the NIF target chamber and then again during its removal after the experiment. During this time, personnel would be close to a large, open target chamber port. Because they would have a line-of-sight view to the activated target chamber interior, activated as a result of previous experiments, they would receive some amount of exposure. Appropriate protective measures for plutonium exposure would be used during post-experiment activities.

The inner containment vessel would not be activated during nonyield experiments. Thus, no additional routine exposure would be expected if the post-experiment inner containment vessel needs to be accessed to retrieve debris for analysis or during packaging of the inner containment vessel as waste. For 10 nonyield plutonium experiments per year, the additional exposure incurred during inner containment vessel placement and removal from the target chamber would be no more than 1 person-rem per year.

For yield experiments with plutonium, an additional exposure would occur during handling of the post-experiment inner containment vessel; i.e., placement and removal, accessing it to retrieve debris for analysis, and packaging it as waste. This dose would occur mostly as a result of exposure to the activated inner containment vessel. This additional dose was estimated assuming 4 plutonium yield experiments per year, at 45 megajoules each. An additional 3 person-rem per year of worker exposure could result from these plutonium yield experiments.

In addition, a worker dose would be incurred during routine decontamination activities. This would include handling of contaminated/activated items; disassembling them, if needed; and processing them through the decontamination systems. This dose would be largely related to the cleaning frequency, which is expected to be once per year. Thus, this component of the worker dose would not change under the Proposed Action. Table M.5.3.14.1–1 presents the calculated radiation doses to the public, the NIF workers, and noninvolved workers during normal operations.

TABLE M.5.3.14.1–1.—*Radiological Impacts to the Public and Workers from Normal Operations (Proposed Action)*

Receptor	Proposed Action		No Action Alternative	
	Dose	Latent Cancer Fatality Risk	Dose	Latent Cancer Fatality Risk
Public (site-wide MEI)	0.27 mrem/yr	1.6×10^{-7}	0.24 mrem/yr	1.4×10^{-7}
Population	0.29 person-rem/yr	1.7×10^{-4}	0.26 person-rem/yr	1.6×10^{-4}
Involved workers	<19 person rem/yr	0 cancers in population (calculated value = 1.1×10^{-2})	<15 person-rem/yr	0 cancers in population (calculated value = 9×10^{-3})
Noninvolved worker	1 mrem/yr	6×10^{-7}/yr of exposure	1 mrem/yr	6×10^{-7}/yr of exposure

Source: LLNL 2003d.
MEI = maximally exposed individual; mrem = millirems; yr = year.

The dose at the site boundary would be dominated by neutron skyshine; direct dose would be small by comparison. The NIF MEI dose from airborne releases would be 0.068 millirem per year (Section M.5.3.8.4). When added to the 0.2 millirem per year dose from the skyshine, the total MEI dose from the NIF operations under the Proposed Action would be 0.27 millirem per year. This dose would be less than 0.3 percent of DOE standard and would result in an increase in annual latent cancer fatality risk of 1.6×10^{-7}. The skyshine would not result in any increase in the overall population dose because the exposure to the skyshine would be limited to close proximity to LLNL boundary next to the NIF.

M.5.3.14.2 *Nonradiological Exposure*

Potential nonradiological impacts to human health and safety posed by the NIF operations under the Proposed Action would include chemical exposure and risks of occupational injuries, illnesses, and fatalities resulting from normal, accident-free, operations and potential laser exposure. Involved and uninvolved workers could be affected.

The potential exists for personnel exposures due to an increased amount of beryllium as well as alkali metals resulting from the NIF operations under the Proposed Action. Beryllium- and lithium- containing targets would contribute to airborne and surface contamination. This contamination would be contained within the NIF target chamber. Personnel exposures to these contaminants would be controlled through the implementation of ES&H requirements, specifically Document 14.4, *Implementation of the Chronic Beryllium Disease Prevention Program Requirements,* and Document 14.7, *Safe Handling of Alkali Metals and Their Reactive Compounds.* Personnel monitoring and area decontamination practices would be employed to reduce the contamination source term and to minimize hazards to facility workers.

The use of chemicals under the Proposed Action would be the same as discussed in Section M.5.2.13.2, and would not necessarily result in additional worker exposures. Thus, no adverse impacts from this action would be expected.

M.5.3.14.3 *Physical Hazards*

The NIF would use powerful lasers. Powerful lasers are hazardous to the eyes and skin, whether exposure is to the direct beam of the laser or reflections. At NIF, laser safety would be particularly important. Laser safety officers would ensure that lasers are operated according to LLNL safety procedures, which is based on integrated safety management techniques. These management techniques would include controlling access to the laser operational area and requiring use of safety interlocks, warning systems and signs, remote operation, and eye protection.

Physical hazards, such as noise, electrical shock, and workplace injuries/illnesses, could increase under the Proposed Action, but workplace injury/illness statistics show a decreasing trend over the past 10 years (see Section M.5.2.14).

M.5.4 Reduced Operation Alternative

Under the Reduced Operation Alternative, the neutron spectrometer would not be constructed and there would be no experiments with plutonium, other fissile materials, fissionable materials (other than depleted uranium without yield), or lithium hydride. The operation of the NIF under the Reduced Operation Alternative would be similar to that under the No Action Alternative. The primary difference would be in the schedule of experiments, the annual yield, and tritium throughput. The Reduced Operation Alternative would stretch the 12-month No Action Alternative experiment schedule into an 18-month experiment schedule. The annual level of operations on the NIF would be reduced from 1,200 megajoules per year to 800 megajoules per year. Section M.3.3 provides additional information on the programmatic impacts of adopting the Reduced Operation Alternative.

M.5.4.1 *Land Use and Applicable Plans*

The generalized land use at LLNL and vicinity is zoned for industrial park use. The industrial land use for the NIF would be the same as outlined under the No Action Alternative. The Reduced Operation Alternative would not result in any change to the land use for the immediate area of the NIF or land use in the overall vicinity. No impacts to land use would be expected from the Reduced Operation Alternative.

M.5.4.2 *Socioeconomic Characteristics and Environmental Justice*

M.5.4.2.1 *Socioeconomics*

The Reduced Operation Alternative would not include the construction of a neutron spectrometer; therefore, there would be no increase in temporary employment due to construction activities.

The projected level of long-term workers that would be needed for this level of operations is 367, with 172 employees for direct operations along with 195 support personnel. There are 380 long-term employees currently associated with the NIF. The current level of workers exceeds the number that would be needed under the Reduced Operation Alternative. The reduction in force of 13 workers would be made through attrition consistent with the 5- to 8-percent annual turnover rate at LLNL, or through internal transfers to other projects. Therefore, no impacts to local housing, schools, or medical services are anticipated.

M.5.4.2.2 *Environmental Justice*

The impacts associated with the operation of the NIF with potential for disproportionate effects would be radioactive air emissions. Beyond a 5-mile radius, these impacts would be negligible (see Section M.5.3.8). Therefore, there would be no disproportionately high and adverse impacts to minority or low-income populations under the Reduced Operation Alternative.

M.5.4.3 *Community Services*

The existing LLNL fire protection and emergency services, police protection, and security services would not change under the Reduced Operation Alternative. The level of services provided currently would not change. Because there would be no substantial change in the workforce, there would be no changes in the socioeconomic impacts and no associated change in school services.

The NIF is generating and would continue to generate waste office paper, cardboard, plastic, sanitary wastes, and other nonhazardous refuse at a rate similar to LLNL as a whole. There would be nothing unique about the refuse generation from the NIF, in terms of waste types or amounts; therefore, this type of waste is projected on a per capita basis. With a projected total of 367 long-term workers at the NIF and its support operations, the projected amount of nonhazardous solid waste would be approximately 367 cubic meters per year. As a conservative estimate, it is assumed that each worker would generate 1 cubic meter of nonhazardous solid waste. This would be a decrease of 33 cubic meters or 8.3 percent of the amount of nonhazardous solid waste generated under the No Action Alternative. Because 380 long-term personnel are already employed at NIF, the decrease of 13 personnel projected under the Reduced Operation Alternative would represent an associated decrease of 13 cubic meters of nonhazardous solid waste from the amount of waste that is already part of the overall LLNL waste figures. This amount represents an approximate 0.3 percent decrease in the site's current generation of nonhazardous waste; therefore, no impacts are expected to the capacity to handle nonhazardous solid waste under the Reduced Operation Alternative.

M.5.4.4 *Prehistoric and Historic Cultural Resources*

No prehistoric archaeological resources have been identified on or near the NIF site. No buildings and facilities at LLNL that may have potential to be eligible to the NRHP are located near the NIF. Because much of the NIF site has been developed, the likelihood of finding unrecorded and undisturbed prehistoric sites is low. Under the Reduced Operation Alternative, the neutron spectrometer would not be built. There would be no impacts expected to prehistoric or historic cultural resources from the Reduced Operation Alternative.

M.5.4.5 *Aesthetics and Scenic Resources*

The NIF conventional facility construction is now complete. All conventional facilities are constructed and turned over for equipment installation. No further changes to the visual features would occur in the area of the NIF. There would be no impacts to aesthetic and scenic resources under the Reduced Operation Alternative.

M.5.4.6 *Geologic Resources*

The NIF conventional facility construction is now complete. No further excavation is planned, therefore, no impacts to soils would result from the Reduced Operation Alternative. Animal fossils have been found beneath the NIF; however, no new excavation is planned under the

Reduced Operation Alternative. No further impacts to soils or fossils would result from the Reduced Operation Alternative.

M.5.4.7 *Ecology*

The NIF conventional facility construction is complete. No new construction would occur under the Reduced Operation Alternative; therefore, there would be no erosion or changes to existing stormwater flow patterns. No impacts would occur to the nearby wetland area. Few impacts would occur to biological resources during operation of the NIF. The traffic to and from the NIF would have associated losses of road-killed individuals of some species. No adverse impacts to threatened and endangered species or species of special concern are expected from operation of the NIF.

M.5.4.8 *Air Quality*

During normal operations, some experiments at the NIF would result in atmospheric releases of small quantities of tritium and some radionuclides produced by activation of gases in the target bay air.

Some nonradiological hazardous materials would be present at the NIF. Routine emissions of these types of materials would be expected from operation of electrical equipment, wipe cleaning, and occasional use or maintenance testing of the standby generators. The total emissions would be a small fraction of project significance levels and threshold levels for conformity.

M.5.4.8.1 *Criteria Air Pollutants*

The emission of criteria air pollutants would be dominated by the operation of the facility rather than the experiments. Therefore, the emissions that would result from normal operations of the NIF under the Reduced Operation Alternative are equivalent to those that would be expected from normal operations under the No Action Alternative. The criteria air pollutant emissions would occur primarily from solvent cleaning and fuel combustion. These activities would be the same under the Reduced Operation Alternative as under the No Action Alternative.

M.5.4.8.2 *Hazardous Air Pollutants*

LLNL evaluates a list of approximately 200 compounds to confirm applicability under NESHAP. Emissions of hazardous air pollutants for all of LLNL would be less than one-half of the threshold of 7 tons per year for a single hazardous air pollutant or 15 tons per year for a combination of hazardous air pollutants (LLNL 2002ae). The normal operations of the NIF under the Reduced Operation Alternative would not result in the emission of hazardous air pollutants, except for possible beryllium emissions, well below the toxic air contaminant threshold.

M.5.4.8.3 *Toxic Air Emissions*

Under the Reduced Operation Alternative, the toxic air emissions at the NIF would decrease because of the reduced number of experiments per year. In general, the emissions would be one-third less than those associated with the No Action Alternative.

No increase in impacts from LLNL hazardous air pollutants and toxic air emissions would occur under the Reduced Operation Alternative. The increase in the emission of VOCs would be bounded at 15 percent. The impacts of the increase would be minor.

M.5.4.8.4 *Radiological Air Quality*

During normal NIF operations under the Reduced Operation Alternative, experiments would result in normal atmospheric releases of small quantities of tritium and some radionuclides produced from activation of gases in the target bay air. The total annual inventories of radioactive gases produced relates directly to annual yield. Therefore, the annual inventory produced under the Reduced Operation Alternative would be less than that of the No Action Alternative. Annual emissions of activated gases, based on 800 megajoules per year of yield, are provided in Table M.5.4.8.4–1. Up to 30 curies per year of tritium would be released during maintenance activities, when equipment would be opened up or brought up to air.

TABLE M.5.4.8.4–1.—*Routine Radiological Air Emissions from the National Ignition Facility (Reduced Operation Alternative)*

Nuclide Produced	Nuclide half-life	Production (Ci/year)	Emissions (Ci/year)
Activated Air:			
Hydrogen-3	12.33 yr	2.88×10^{-3}	2.88×10^{-3}
Carbon-14	5730 yr	8.67×10^{-4}	8.67×10^{-4}
Nitrogen-13	9.99 min	3.41×10^{2}	4.52×10^{1}
Nitrogen-16	7.13 sec	5.61×10^{4}	1.02×10^{2}
Sulfur-37	5.06 min	7.40	5.29×10^{-1}
Chlorine-40	1.42 min	4.27×10^{1}	8.60×10^{-1}
Argon-41	1.83 hr	2.79×10^{1}	1.75×10^{1}
Tritium (releases during maintenance)			**30**

Source: LLNL 2003d.
Ci = curies; hr = hours; min = minutes; sec = seconds; yr = year(s).

Table M.5.4.8.4–2 presents the potential impacts of radiological air emissions to the public. While some of the radiation exposures from normal operations to workers would result from radiological air emissions, doses to involved workers would be primarily from direct radiation exposure (see Section M.5.4.14.1). The impacts under the No Action Alternative are here presented for comparison.

TABLE M.5.4.8.4–2.—*Radiological Impacts to the General Public from Airborne Effluent Emissions during Normal Operations (Reduced Operation Alternative)*

Receptor	Reduced Operation Alternative		No Action Alternative	
	Dose	Latent Cancer Fatality Risk	Dose	Latent Cancer Fatality Risk
NIF offsite MEI	0.03 mrem/yr	1.8×10^{-8} /yr of exposure	0.04 mrem/yr	2.4×10^{-8} /yr of exposure
Population Dose	0.24 person-rem/yr	1.4×10^{-4}	0.26 person-rem/yr	1.6×10^{-4}

Source: LLLNL 2003d.
MEI = maximally exposed individual; mrem = millirems; yr = year; NIF = National Ignition Facility.

The baseline dose to the MEI from Livermore Site operations (site-wide MEI) without the NIF operation would be 0.017 millirem per year with an associated population dose of 0.16 person-rem per year (SNL 2000). Due to planned increases in Building 331 tritium releases, the LLNL SW/SPEIS Reduced Operation Alternative dose to the site-wide MEI without the NIF operations would be 0.039 millirem per year. The location of the site-wide MEI would correspond with the NIF MEI location. Conservatively, adding the site-wide MEI Reduced Operation Alternative dose to the NIF MEI dose for airborne effluent emissions would result in an estimated dose of 0.068 millirem per year for airborne releases under the NIF Reduced Operation Alternative. This dose would be less than 0.7 percent of the NESHAP limit. The component of population dose from routine NIF releases would be 0.24 person-rem per year. Adding 0.24 person-rem per year to LLNL SW/SPEIS Reduced Operation Alternative population dose of 0.89 person-rem per year would result in a dose of 1.1 person-rem per year. This population dose would be many orders of magnitude less than the dose received from natural background. No adverse impacts on radiological air quality would be expected from the Reduced Operation Alternative.

M.5.4.9 *Water*

Under the Reduced Operation Alternative, the neutron spectrometer would not be built; therefore, there would be no changes to stormwater flow and no impacts to surface water or groundwater resources from construction activities.

Water usage at the NIF is currently expected to be 27.6 million liters per day or approximately a 3.5 percent increase in LLNL usage; i.e., 795 million liters per year in 2001. Under the Reduced Operation Alternative, there would be some reduction in water usage, but the difference would be minor. The reduction, though minor, could be of beneficial impact in drought years.

M.5.4.10 *Noise*

While the level of operations of the NIF would be reduced under the Reduced Operation Alternative, the manner of operation of the NIF facility would be similar. The main sources of noise from the operation of the NIF would be the HVAC systems and traffic associated with an industrial facility, moving equipment, and truck deliveries; i.e., approximately 85 decibels. The noise at the NIF would be equal to other local industrial/commercial activities. The contribution of these activities to noise levels offsite would be small. Noise resulting from the NIF experiments would be heard outside the NIF building for a short distance only. This noise would be momentary and intermittent, occurring only at the time of a, experiment, up to 6 times per day. The impacts of noise to workers would be normal for industrial facilities. With standard hearing protection, no impacts from noise would be expected. No impacts would be expected from noise to the public.

M.5.4.11 *Traffic and Transportation*

Traffic

The construction of the NIF conventional facilities is completed. As a result, the traffic associated with the construction workers has ceased. The personnel who are working to make the NIF operational and will operate the NIF are already employed onsite. Therefore, there would be no change in the amount of traffic that currently exists. Slightly fewer employees would operate the NIF under the Reduced Operation Alternative, resulting in a slight reduction in traffic from current levels.

Radiological Transportation

The consideration of target fill activities and the exact facilities that would perform these activities has not yet been fully decided. These activities would undergo NEPA and safety review prior to initiation. Most of the targets would be provided from an onsite source. Routine onsite transportation of targets would have no impact to the public as access to LLNL is restricted. The onsite transportation would fall within the scope of operational activities already analyzed for the site and the NIF in particular.

The major offsite source of target material would be Los Alamos National Laboratory. Under the Reduced Operation Alternative, 3 shipments per year, each with 0.2 gram of depleted uranium; and 10 shipments per year, each with 100 curies of tritium, would occur. The radiological transportation analysis is based on the assumption that these would all be separate shipments.

For incident-free transport; i.e., no accidents, of the depleted uranium, the consequence would be the radiation dose potentially received by the truck drivers and members of the public driving on the highways, living near the highways, and present at rest stops. Because of the very small amount of radioactive material being transported and the shielding of the containers and truck, the radiation dose rate near the truck is expected to be immeasurably small. Therefore, there would be no incident-free radiation dose to drivers or members of the public.

Tritium does not produce an external dose rate. Therefore, transport of tritium would also have no incident-free radiological impacts. Section M.5.6 presents the consequences of transportation accidents, which include tritium transport accidents.

M.5.4.12 *Utilities and Energy*

Under the Reduced Operation Alternative, fewer NIF experiments would be implemented per year. However, the facility would be operated at clean-room conditions irrespective of the number of experiments. The utility usage would be dominated by the operation of the facility as a clean room. The reduction in utility usage would be minor, as the overall operation of the NIF would not be greatly reduced. The utility usage would be only slightly less than that discussed under the No Action Alternative.

M.5.4.13 *Materials and Waste Management*

NIF research activities would use a variety of hazardous; i.e., radioactive and toxic, materials and nonhazardous materials. All of these would become part of material management for the NIF. The primary strategy for the control and management of hazardous materials at the NIF would be to minimize exposures to hazardous substances in accordance with regulatory requirements, institutional goals, and best management practices. Once the materials have been used, they would be classified and managed under the NIF's and LLNL's waste management procedures. Waste management is discussed in Section M.5.4.13.3. During the use and management of these materials, air emissions would occur. Emissions are discussed in Section M.5.4.8.

Particulates would be generated in the target chamber from each experiment. When the cleanup of the target chamber occurs, the particulates and debris would be added to the waste streams discussed in Section M.5.4.13.3. The management of the radioactive particulates and tritium is discussed in Section M.5.4.13.1. The remaining particulates and hazardous materials are discussed in Section M.5.4.13.2.

M.5.4.13.1 *Radionuclide Materials Management*

The materials contained in targets and the activation of materials in the target area described under the No Action Alternative would be the same for the Reduced Operation Alternative. Under the Reduced Operation Alternative, the inventories of activated material in the target chamber and the gases from the target bay air would be the same as under the No Action Alternative, because this would be largely determined by the individual experiment yield.

Particulates would be generated in the same manner as described under the No Action Alternative. Because these are mostly short-lived species, the maximum inventories would be found in the target chamber shortly after the last experiment and well before cleanup. By the time cleaning occurs or components are removed, the radioactive particulate inventory would have decayed to much smaller quantities. Under the Reduced Operation Alternative, there would be longer periods between experiments and potentially more time for the inventory to decay before cleanup.

Depleted Uranium

Under the Reduced Operation Alternative, depleted uranium would be handled and used in the same manner as under the No Action Alternative.

Tritium

Under the Reduced Operation Alternative, tritium would be handled and used in the same manner as under the No Action Alternative.

M.5.4.13.2 *Nonradiological Materials Management*

The management of nonradiological materials would be the same as described under the No Action Alternative. Waste is discussed in Section M.5.4.13.3.

The amount of nonradiological particulates that would be generated under the Reduced Operation Alternative would be similar to, but less than, that generated under the No Action Alternative (Table M.5.2.13.2–1). The exact amount would depend on the type and schedule of the experiments.

The nonradiological materials expected to be used on the NIF under the Reduced Operation Alternative would be the same as those used under the No Action Alternative (see Table M.5.2.13.2–2).

M.5.4.13.3 *Waste Management*

Under the Reduced Operation Alternative, many of the waste streams from the NIF would be unchanged from those of the No Action Alternative, as the difference in operations would not be directly related to annual yield. For the waste streams that are related to yield or the number of experiments, such as target chamber hardware or decontamination wastes, changes would be in proportion to the differences in annual yield. Under the Reduced Operation Alternative, the cleaning schedule would be performed over 18 months compared to the 12-month cleaning schedule under the No Action Alternative. The Reduced Operation Alternative would generate proportionately less waste than the No Action Alternative on an annual basis. A summary of the waste stream estimates for the Reduced Operation Alternative is provided in Table M.5.4.13.3–1.

M.5.4.13.3.1 *Radioactive Waste and Mixed Waste*

Wastes from Wipe Cleaning, Chemical Treatment, and Decontamination

Wipe cleaning is primarily related to maintaining clean-room conditions. These conditions would be maintained even under a reduced schedule. Therefore, the waste from wipe cleaning would be the same as under the No Action Alternative. While the type of experiments expected under the Reduced Operation Alternative would be the same as under the No Action Alternative, the schedule would be extended with more time between each experiment. Under the Reduced Operation Alternative, it would take 18 months to perform the same number of experiments that would be performed in 12 months under the No Action Alternative. This lengthening of the experiment schedule would result in the expansion of the schedule for chemical treatment and decontamination of the target chamber. Under the Reduced Operation Alternative, the target chamber would be decontaminated once per 18 months instead of annually. Therefore, the impacts associated with the decontamination activities would be proportionately less on an annual basis.

TABLE M.5.4.13.3–1.—*National Ignition Facility Annual Waste Estimates for Low-Level, Mixed, and Hazardous Wastes for the Reduced Operation Alternative*

Source of Waste	Low-Level		Mixed		Hazardous	
	Solid (m^3)	Liquid (m^3)	Solid (m^3)	Liquid (m^3)	Solid (m^3)	Liquid (m^3)
Tritium processing	3.2	–	0.003	–	–	–
Wipe cleaning	3.3	0.30	1.00	–	1.0	–
HEPA filters/pre-filters	0.23	–	–	–	–	–
Waste hardware	42	–	0.33	–	–	–
Chemical treatment/decontamination	–	0.65	0.20	3.3	–	1.5
Waste oils/equipment	0.06	–	–	0.2	7.5	0.2
General chemicals	–	–	–	–	–	4.6
Total/year	**49**	**0.95**	**1.6**	**3.5**	**8.5**	**6.3**
No Action Alternative Total/year	70	1.6	1.8	5.1	8.5	6.3

Source: LLNL 2003d.
HEPA = high-efficiency particulate air; m^3 = cubic meters.

Waste Hardware

The amount of waste hardware would be reduced by one-third under the Reduced Operation Alternative. The target chamber components, such as debris shields and first wall panels, would last 50 percent longer.

M.5.4.13.3.2 *Hazardous Waste*

The waste oils and associated equipment would be the same as discussed under the No Action Alternative. The general chemicals waste would also be the same as under the No Action Alternative.

M.5.4.14 *Occupational Protection and Human Health*

M.5.4.14.1 *Radiological Exposure*

Personnel would be exposed to two sources of prompt radiation during the NIF yield operations: direct radiation and skyshine. These exposure pathways would be reduced by one-third for the 800-megajoule per year Reduced Operation Alternative, compared to the 1,200-megajoule per year level under the Proposed Action and No Action Alternative. For the Reduced Operation Alternative, the skyshine dose at the nearest site boundary (350 meters due east of the target bay) would be less than 0.13 millirem per year for all possible target illumination configurations. The dose at the site boundary would be dominated by neutron skyshine; the direct dose would be small by comparison.

Personnel within the NIF would also receive a direct dose. Operations personnel, located in the main control room, would receive a direct dose of about 3 millirems per year. Those in the diagnostics building would receive about 2 millirems per year, and those in the optics assembly building would receive approximately 0.7 millirem per year. These direct doses are based upon a 40-hour workweek.

Finally, noninvolved workers moving past the target chamber end of the NIF would receive a direct dose of approximately 0.7 millirem per year, assuming an occupancy of 30 minutes each day for walkways and roads, as recommended by the National Council on Radiation Protection (NRC 1977a). Table M.5.4.14.1–1 presents the calculated radiation doses to the public and the NIF workers and noninvolved workers during normal operations.

TABLE M.5.4.14.1–1.—*Radiological Impacts to the Public and Workers from Normal Operations (Reduced Operation Alternative)*

Receptor	Reduced Operation Alternative		No Action Alternative	
	Dose	Latent Cancer Fatality Risk	Dose	Latent Cancer Fatality Risk
Public (site-wide MEI)	0.16 mrem/yr	9.6×10^{-8}	0.24 mrem/yr	1.4×10^{-7}
Population	0.24 person-rem/yr	1.4×10^{-4}	0.26 person-rem/yr	1.6×10^{-4}
Involved worker	<10 person rem/yr	0 cancers in population (calculated value = 6×10^{-3})	<15 person-rem	0 cancers in population (calculated value = 9×10^{-3})
Noninvolved worker	1 mrem/yr	6×10^{-7}/yr of exposure	1 mrem/yr	6×10^{-7}/yr of exposure

Source: LLNL 2003d.
MEI = maximally exposed individual; mrem = millirems; yr = year.

The NIF MEI dose from airborne releases would be 0.029 millirem per year (Section M.5.4.8.4). When added to the 0.13-millirem per year dose from the skyshine, the total NIF MEI dose from the NIF operations under the Reduced Operation Alternative would be 0.16 millirem per year. This dose would be less than 0.2 percent of DOE standard and would result in an increase in annual LCF risk of 9.6×10^{-8}. The skyshine would not result in any increase in the overall population dose because the exposure to the skyshine would be limited to close proximity to LLNL boundary next to the NIF.

M.5.4.14.2 *Nonradiological Exposure*

The use of chemicals under the Reduced Operation Alternative would be the same as discussed in Section M.5.2.13.2 and would not necessarily result in additional worker exposures. Continued application of site ES&H and Integrated Safety Management System principles would result in minimal impacts to workers and the public. Thus, no adverse impacts from this action would be expected.

M.5.4.14.3 *Physical Hazards*

The NIF would use powerful lasers. Powerful lasers are hazardous to the eyes and skin, whether exposure is to the direct beam of the laser or reflections. Laser safety would be particularly important at the NIF. Laser safety officers would ensure that lasers would be operated according to LLNL safety procedures, which are based on integrated safety management techniques. These management techniques would include controlling access to the laser operational area and requiring use of safety interlocks, warning systems and signs, remote operation, and eye protection.

Physical hazards, such as noise, electrical shock, and workplace injuries/illnesses, under the Reduced Operation Alternative would remain the same as under the No Action Alternative or decrease slightly, but workplace injury/illness statistics show a decreasing trend over the past 10 years (see Section M.5.2.14).

M.5.5 Mitigation Measures

The regulations promulgated by the CEQ to implement the procedural provisions of NEPA (42 U.S.C. §4321) require that an EIS include a discussion of appropriate mitigation measures (40 CFR §§1502.14[f] and 16[h]). Mitigation measures are discussed in Chapter 5.6 of this LLNL SW/SPEIS. The resource areas for mitigation are waste management and occupational protection (worker dose). The NIF mitigation action plan (DOE 1997a), developed as part of the SSM PEIS, discusses mitigation of waste generation and will remain in effect until completion of the NIF project. As indicated in Chapter 5.6, occupational exposure will be kept as low as reasonably achievable.

M.5.6 Accident Analysis

NEPA requires that an agency evaluate reasonably foreseeable significant adverse effects on the human environment in an EIS. This section informs the decision-maker and the public about the chances that reasonably foreseeable accidents associated with the NIF, including the No Action Alternative, Proposed Action, and Reduced Operation Alternative, could occur, and about their potential adverse consequences. An accident is considered bounding if no reasonably foreseeable accident can be found with greater consequences. An accident is reasonably foreseeable if the analysis of occurrence is supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason (40 CFR §1502.22[b][4], DOE 1993b, DOE 2002t).

This section presents the potential impacts on workers (both involved and noninvolved) and the public due to potential accidents associated with operation of the NIF. An accident is a sequence of one or more unplanned events with potential outcomes that endanger the health and safety of workers and the public. An accident can involve a combined release of energy and hazardous materials (radiological or chemical) that might cause prompt or latent health effects. The sequence usually begins with an initiating event, such as a human error, equipment failure, or earthquake, followed by a succession of other events that could be dependent or independent of the initial event, which dictate the accident's progression and the extent of materials released. Initiating events fall into three categories:

- *Internal initiators* normally originate in and around the facility, but are always a result of facility operations. Examples include equipment or structural failures and human errors.
- *External initiators* are independent of facility operations and normally originate from outside the facility. Some external initiators affect the ability of the facility to maintain its confinement of hazardous materials because of potential structural damage. Examples include aircraft crashes, vehicle crashes, and nearby explosions.
- *Natural phenomena initiators* are natural occurrences that are independent of facility operations and occurrences at nearby facilities or operations. Examples include earthquakes, high winds, floods, and lightning. Although natural phenomena initiators are independent of external facilities, their occurrence can involve those facilities and compound the progression of the accident.

If an accident were to occur involving the release of radioactive or chemical materials, workers, members of the public, and the environment would be at risk. Workers in the facility where the accident occurs would be particularly vulnerable to the effects of the accident because of their location. The offsite public would also be at risk of exposure to the extent that meteorological conditions exist for the environmental dispersion of released hazardous materials. Using approved computer models, the atmospheric dispersion of released hazardous materials and their effects were predicted. However, prediction of latent potential health effects becomes increasingly difficult to quantify for facility workers as the distance between the accident location and the worker decreases. This is because the individual worker exposure cannot be precisely defined with respect to the presence of shielding and other protective features. The worker also may be injured or killed by physical effects of the accident itself.

This section presents the potential impacts on workers (both involved and noninvolved) and the public from accidents associated with operation of the NIF. Additional details supporting the information presented here are provided in Appendix D.

M.5.6.1 *Radiological Accident Scenarios*

M.5.6.1.1 *No Action Alternative*

A review was conducted of accidents potentially resulting in a radiological release from the NIF under the No Action Alternative (LLNL 2003d.). These scenarios included:

- Operational upsets resulting in tritium release
- Loss of target chamber vacuum
- Waste drum fire
- Release during decontamination operations
- Worker contamination/exposure scenarios
- Earthquakes and other natural phenomena
- External events; e.g., aircraft crash

These scenarios would have varying probabilities and consequences. They also would have differing release fractions and could occur at different times after the experiment. To encompass all potential radiological consequences from NIF operations, a bounding scenario resulting in the release of radionuclides to the environment was identified. The initiating event would be a severe earthquake; i.e., beyond design basis. The scenario considers an earthquake of frequency 10^{-4} per year (~ 1*g* horizontal ground acceleration) occurring at the time of a maximum credible yield experiment. Assuming 100 high-yield experiments per year, the estimated frequency of the accident would be 2×10^{-8} per year, assuming a 1-minute time window for the earthquake. The target bay has been shown to withstand a severe earthquake (LLNL 2003d), but other areas and components have not been analyzed beyond their design basis. The beam tubes leading from the switchyard into the target chamber were assumed to fail in the proposed earthquake. The switchyards could withstand the earthquake, but were conservatively assumed to collapse.

Inventories vulnerable to release in the target bay would include activated gases in the air and beam tubes and activated material in the target chamber. For inventories in the target bay, a pathway out to the environment would be created through the beam tube penetrations in the target bay walls. Dispersion in the environment would take place as the material is transported downwind.

Tritium sources located outside the target bay in the laser and target area building would also be vulnerable to release. These primarily would include tritium in elemental form as stored targets or on the cryopumps, or tritium as oxide on the molecular sieve of the tritium processing system. Further, natural gas piping would be located in areas of the laser and target area building outside the target bay. Thus, localized fires outside the target bay could be expected under these extreme conditions (LLNL 2003d).

Aircraft Crash

The probability of a light aircraft crash impacting the NIF laser and target area building would be a credible event; the frequency of occurrence would be approximately 1.6×10^{-4} per year. Specific areas of concern from a release of material standpoint would be the tritium-handling and processing/decontamination areas and the laser bays. If the aircraft crashed into other areas of the laser and target area building, there would be facility damage, but the accident would not result in the release of radioactive material.

The NIF target bay is constructed of thick, reinforced concrete. The primary purpose of this construction is radiological shielding; however, as an additional benefit, the construction also makes the facility essentially impervious to impact by light aircraft. Should an aircraft crash into the target bay, the chief hazard would be to the occupants of the aircraft and any onsite personnel in the way of falling plane wreckage and burning aviation fuel. The thickness of the reinforced concrete walls and roof are such that they would withstand the impact of a direct hit from a light aircraft. The switchyard is also constructed of reinforced concrete, a minimum of 0.61 meters thick. This area is also impervious to a light aircraft. See Section M.5.6.2.1 for discussion of potential chemical releases from an aircraft crash.

Source Terms

Radioactive inventories vulnerable to release include activated gases, activated particulates in the target chamber, and tritium.

Activated Gases

If the earthquake were to occur immediately after a high-yield experiment, air activation products in the target bay atmosphere and beam tubes would be available for release. Inventories of activated gases created in the target bay atmosphere as a result of a maximum yield experiment are provided in Table M.5.2.8.4–1 in Section M.5.2.8.4.

A direct pathway to the environment could be created by the seismic event, resulting in the release of activated air from the target bay. The activated air would be forced out as the wind blows from one collapsed switchyard, through the beam tube penetrations on one side of the target bay, through the target bay, and then out through the beam tube penetrations and collapsed switchyard on the opposite side. No mitigation is assumed.

Activated Particulate

A small quantity of activated debris would be created in the target chamber. Conservatively, for the purpose of this analysis, it is assumed that all of this solid debris would exist as fine particulates.

The particulates would accumulate in the target chamber until a scheduled cleanup. It is conservatively assumed here that the material would accumulate in the target chamber for one year. The bounding annual radionuclide particulate dispersible target chamber inventories; i.e., the inventory in the form of particulates, subsequent to the last yield experiment of the year, assumed to be at the maximum credible yield of 45 megajoules, are provided in Table M.5.2.13.1–1 in Section M.5.2.13.1.

Collapse of the beam tubes and failure of debris shields, diagnostic windows, etc., would open many penetrations to the target chamber. This would allow rapid air ingress to the target chamber. The inflow of air would disturb any settled particulates, causing them to become airborne within the target chamber. A conservative airborne release fraction of 10^{-3} for solid particulate is assumed. With rapid air ingress that is assumed to occur in the event, some of the particulates on the surface could become airborne due to resuspension mechanisms. Resuspension occurs as a result of mechanical disturbances as well as by wind. In what follows, a simple method would be used to estimate the airborne release fraction (ARF), based on the resuspension data. The ARF is used to estimate the release of material in particulate form to the environment.

The resuspension factor is defined as:

$$RF = \text{airborne concentration} / \text{surface concentration}$$

Applying the definition of RF to the target chamber, leads to the following:

$$\begin{aligned} RF &= (\text{airborne particulate} / 4\pi/3 \times R^3) / (\text{particulate on surface}/4\pi \times R^2) \\ &= (3/R) \times (\text{airborne particulate/ particulate on surface}) \\ &= (3/R) \times ARF \end{aligned}$$

Where,

R is the radius of the target chamber.

Thus,

$$ARF = (R/3) \times RF$$

The value for the resuspension factor, RF, would range from 10^{-9} to 10^{-4} for wind resuspension and from 10^{-7} to 10^{-3} for mechanical disturbance (LLNL 2003d). Using the target chamber radius of 5 meters, the ARF would range from 10^{-9} to 10^{-3}. In this evaluation, the conservative value of 10^{-3} is used for the ARF. According to DOE-STD-1027, an average ARF of 10^{-3} is used generally for solids, powders, and liquids for various accidents in facility categorization.

Some deposition of the particulates would occur within the target chamber and target bay. Including in-facility deposition would reduce the quantity of radioactive material reaching the environment. This has not been considered at this time. Thus, a conservative source term has been estimated.

Tritium

Tritium would arrive at the facility in targets containing up to 35 curies; an additional 35 curies could be in the associated support structure, for a total maximum target assembly inventory of 70 curies. No more than 100 curies of tritium would be in the facility in the form of targets and associated support structure. Individual targets would be placed in the target chamber for experiments. Unburned tritium would be exhausted and retained in the tritium processing system. The inventory in the collection system could be controlled and maintained such that the maximum facility in-process inventory would not exceed 500 curies. This would be accomplished by active inventory control and periodic removal of the molecular sieve and transfer to shipping containers for disposal or recovery offsite.

The seismic event could lead to the release of any tritium contained in targets. Release could occur as a result of direct crushing of the targets or failure of the cryogenic support system leading to pressurization and failure of the capsule. This tritium would be released from the targets in the elemental form. There could be small quantities of flammables, such as solvents, in the area; therefore, there exists the small possibility of a fire. It is presumed that the fire mitigation system would be unavailable during this event. For the purpose of this severe accident analysis, the probability of the fire occurring and continuing for some time is taken to be 1.0. Thus, any tritium released from targets is conservatively assumed to become oxidized and to be released as tritiated water. Because the targets would be stored in an area that could be severely damaged by this earthquake, the tritium released from the targets would directly enter the environment.

During the hypothesized seismic event, it is possible that there would be damage to components of the tritium processing system. These are designed to survive the design-basis earthquake. Their behavior in more severe earthquakes is not known, and thus, these components are assumed to fail; i.e., the molecular sieve would be directly exposed to the atmosphere. Under the extreme conditions of this accident, a fire could occur near the tritium processing system. This would provide an energy source for the release of the tritium from the molecular sieve directly into the atmosphere. It is also possible that water piping in the area would fail, leading to flooding. Water sources could include domestic water, low conductivity water, and fire protection water. It is much more likely that the domestic and low conductivity water supplies would fail when compared to the fire sprinkler system. The sprinkler system has been designed to National Fire Protection Association standards and would survive the design-basis earthquake. Because the behavior of the sprinkler system under more severe seismic loads is not known, failure is postulated. If this were the case, any fire in the area would be unmitigated. If the area is flooded, an alternate release pathway is provided. Flooding would provide the opportunity for exchange with the material absorbed on the molecular sieve and would result in tritium contamination of the water pool. Subsequent evaporation from the pool would release the tritium to the environment via the airborne pathway, although at a much slower rate than the fire release mechanism. In either case, the tritium would directly enter the environment, as the tritium processing area is located outside of the target bay in a location that would likely be severely damaged by the earthquake.

The total tritium source term would be 500 curies. The most conservative source term would result from a fire in the area, because the release would occur more quickly and all of the tritium would be released in the more hazardous oxide form. The entire tritium inventory could be released over a short period; 3 minutes would be a conservative estimate to release all of the tritium from the molecular sieve.

For this very severe scenario, 100 percent of the tritium inventory would be released from the decontamination area. The activation product particulate inventories and activated gases mentioned previously also would be released, with a release fraction of 10^{-3} for particulates and 1.0 for gases. The inventories that could be released under severe accident conditions are summarized in Table M.5.6.1.1–1.

TABLE M.5.6.1.1–1.—*National Ignition Facility Laser and Target Area Building Estimated Maximum Radionuclide Inventories Released Under Severe Accident Conditions for the No Action Alternative*

Radionuclide	Quantity (Ci)
Total tritium	500
Activated particulates[a]	
Sodium-24	4.0×10^{-4}
Manganese-56	1.3×10^{-3}
Cobalt-60	7.4×10^{-5}
Manganese-54	1.4×10^{-4}
Scandium-48	3.6×10^{-5}
Iron-55	7.1×10^{-4}
Scandium-46	4.6×10^{-5}
Calcium-45	1.0×10^{-4}
Scandium-44	2.0×10^{-4}
Tantalum-182	2.5×10^{-5}
Scandium-44m	6.4×10^{-5}
Gadolinium-153	2.5×10^{-5}
Nickel-65	2.0×10^{-4}
Copper-64	1.5×10^{-3}
Cobalt-62m	1.6×10^{-4}
Lead-203	1.6×10^{-5}
Scandium-47	2.4×10^{-5}
Potassium-42	1.8×10^{-5}
Gallium-72	2.8×10^{-6}
Hafnium-181	2.8×10^{-6}
Gadolinium-159	8.6×10^{-5}
Chromium-51	4.7×10^{-5}
Dysprosium-159	4.2×10^{-6}
Europium-156	7.9×10^{-7}
Nickel-63	8.8×10^{-6}
Depleted uranium[b]	
Uranium-234	8.6×10^{-10}
Uranium-235	4.0×10^{-11}
Uranium-238	1.6×10^{-9}

TABLE M.5.6.1.1–1.—*National Ignition Facility Laser and Target Area Building Estimated Maximum Radionuclide Inventories Released Under Severe Accident Conditions for the No Action Alternative (continued)*

Radionuclide	Quantity (Ci)
Activated gases[c]	
Target bay air	
Hydrogen-3	1.6×10^{-4}
Nitrogen-13	1.9×10^{1}
Nitrogen-16	3.2×10^{3}
Sulfur-37	4.2×10^{-1}
Chlorine-40	2.4
Argon-41	1.6
Carbon-14	4.9×10^{-5}
Beam tubes	
Hydrogen-3	4.7×10^{-6}
Sulfur-35	2.3×10^{-5}
Argon-37	4.1×10^{-4}
Argon-39	1.7×10^{-3}
Argon-41	3.5

Source: LLNL 2003d.
[a] After one year of operation without cleanup; corresponds to a final 45-MJ experiment, ending a year with a 1,200-MJ total yield.
[b] Depleted uranium would be used only in non-yield experiments and would, therefore, not be considered “activated,” and no fission products would be produced. Depleted uranium is already slightly radioactive; the half-life of uranium-238 (dominant isotope) is 4.5×10^{9} yrs. The assumed composition is 99.64% uranium-238, 0.36% uranium-235, and 0.0028% uranium-234. The quantities listed correspond to the maximum use over a year of 5 g.
[c] After a single 45-MJ experiment.
Ci = curies; g = grams; MJ = megajoules.

It is also possible that water piping in the area would fail, leading to flooding. If the area were flooded, an alternate release pathway would be provided. Flooding would provide the opportunity for exchange with the material absorbed on the molecular sieve and would result in tritium contamination of the water pool. Subsequent evaporation from the pool would release the tritium to the environment via the airborne pathway, although at a much slower rate than the fire release mechanism. In either case, the tritium would directly enter the environment, as the tritium processing area is located outside of the target bay in a location that would likely be severely damaged by the earthquake.

Worker Exposure

The following summarizes worker exposure during accident situations. The bounding airborne radiological accident would be a release of all stored tritium within the NIF. This would results in 0.2 rem of exposure to the NIF worker. This assumes the trained worker will respond properly upon hearing alarms or discovering the situation, secure the work area, and leave the room within ten minutes. This exposure estimate is still well below the 5-rem routine occupational exposure limit.

The bounding radiological exposure accident would result from a worker remaining in the NIF target bay during a yield experiment. Workers could be exposed to lethal doses of neutron and prompt gamma radiation if accidentally present during a yield experiment.

Premature entry into the target bay after a high-yield experiment could also result in 15 rems of worker exposure. This assumes that the individual would remain in the area for one hour. The interlock system and other controls are critical to preventing such exposure. This exposure would be the same under the No Action Alternative, the Proposed Action, and the Reduced Operation Alternative.

M.5.6.1.2 *Proposed Action*

The Proposed Action would not introduce any new types of accident scenarios. Thus, the scenarios considered under the No Action Alternative have been examined with a revised source term for the Proposed Action. Because of facility inventory limits, some materials would not be simultaneously allowed into the facility. Strict inventory controls would be in place and adhered to. Several possible source terms are provided. Consequences have been assessed for the one that would result in the bounding offsite consequences.

Source Terms

Radioactive inventories vulnerable to release include activated gases, activated particulates in the target chamber, and tritium. There would be no change in the activated gas or tritium source terms under the Proposed Action. The activated particulate inventory in the target chamber would change based on the new materials proposed. Gaseous and semivolatile fission products would be present immediately after the experiment and would be vulnerable to release. Alternately, inventories from tracers that would be part of the Proposed Action could also be present. Plutonium experiments would use weapons-grade material for yield experiments, and associated fission products and activated particulates would be formed in the inner containment vessel. These source terms would not all be simultaneously present. The target chamber inventories that would be released during an earthquake under the No Action Alternative are listed in Table M.5.6.1.1–1. The possible additional bounding target chamber inventories that would result for the Proposed Action are listed in Table M.5.6.1.2–1. The source terms under both of these alternatives are summarized in Table M.5.6.1.2–2.

The accident with the highest consequence to the offsite population (Table M.5.6.1.2–3) would be an earthquake during a plutonium experiment without yield. The radiological consequences onsite and at the site boundary are calculated to be higher for this accident than those for any other radiological accident scenario. The radiation dose at the site boundary nearest to the release under median meteorological conditions would be 1.65×10^{-3} rem. Using the dose-to-risk conversion factor of 6×10^{-4} per person-rem, as shown in Table M.5.6.1.2–3, the MEI dose would have a probability of $9.89 \times 10^{-7,}$ or one chance in 1,011,000, of developing a fatal cancer.

The collective radiation dose to the approximately 6,900,000 people living within 50 miles of LLNL under median meteorological conditions was calculated to be 0.546 person-rem. Using the dose-to-risk conversion factor of 6×10^{-4} per person-rem, as shown in Table M.5.6.1.2–3, the collective population dose would result in an estimated 3.28×10^{-4} LCFs to this population.

For onsite personnel, the radiation dose under median meteorological conditions would be 4.99×10^{-3} rem at a distance of 100 meters. Using the dose-to-risk conversion factor of 6×10^{-4} per person-rem, as shown in Table M.5.6.1.2–1, the 100-meter dose would have a probability of 3.00×10^{-6}, or one chance in 334,000, of developing a fatal cancer. The collective radiation dose to the population of noninvolved workers under median meteorological conditions would be 7.41×10^{-1} person-rem. Using the dose-to-risk conversion factor of 6×10^{-4} per person-rem, this collective dose would result in an estimated 4.45×10^{-4} LCFs in this worker population.

The radiation dose at the site boundary nearest to the release under unfavorable meteorological conditions would be 2.16×10^{-2} rem. Using the dose-to-risk conversion factor of 6×10^{-4} per person-rem, as shown in Table M.5.6.1.2–4, the MEI dose would have a probability of 1.30×10^{-5}, or one chance in 77,000, of developing a fatal cancer.

The collective radiation dose to the approximately 6,900,000 people living within 50 miles of LLNL under unfavorable meteorological conditions was calculated to be 8.33 person-rem. Using the dose-to-risk conversion factor of 6×10^{-4} per person-rem, as shown in Table M.5.6.1.2–4, the collective population dose would result in an estimated additional 5.0×10^{-3} LCFs to this population. The calculated risks under this extremely unlikely bounding scenario, even assuming unfavorable meteorology, would be very low and would result in no adverse health impacts to LLNL workers or the offsite population.

For onsite personnel, the radiation dose under unfavorable meteorological conditions would be 4.69×10^{-2} rem at a distance of 100 meters. Using the dose-to-risk conversion factor of 6×10^{-4} per person-rem, as shown in Table M.5.6.1.2–4, the 100-meter dose would have a probability of 2.82×10^{-5}, or one chance in 35,500, of developing a fatal cancer. The collective radiation dose to the population of noninvolved workers under unfavorable meteorological conditions would be 8.23 person-rem. Using the dose-to-risk conversion factor of 6×10^{-4} per person-rem, this collective dose would result in an estimated 4.94×10^{-3} LCFs in this worker population.

Tables M.5.6.1.2-5 and M.5.6.1.2-6 show the frequency and risk of the postulated set of NIF accidents for a noninvolved worker, assumed to be a worker located 100 meters from the release point; the population of noninvolved workers; and the public, maximally exposed offsite individual and the general population living within 50 miles of LLNL, for both median and unfavorable meteorological conditions. The term “risk” means the consequence of the accident; i.e., radiation dose or LCFs, multiplied by the frequency per year for that accident.

M.5.6.2 *Chemical Accident Scenarios*

M.5.6.2.1 *No Action Alternative*

The two types of materials that would be involved in NIF operations and that would contribute to the nonradiological hazard are hazardous chemicals, which would be used at the NIF for a variety of purposes, including cleaning, decontaminating processes, and supporting electrical equipment operation; and material in particulate form. A review was conducted of accidents potentially resulting in a release of nonradiological material from the NIF under the Proposed Action (LLNL 2003d). These scenarios included:

- Spills, such as solvents or decontamination solutions
- Failure of electrical equipment
- Waste drum fire
- Loss of target chamber vacuum/particulate release
- Earthquake or other natural phenomenon
- External event; e.g., aircraft crash

These scenarios would have varying probabilities and consequences. They also would have differing release fractions. To encompass all potential consequences from NIF operations, bounding scenarios have been selected and are discussed below. Table M.5.6.2.1–1 lists the source terms for these chemical accident scenarios.

TABLE M.5.6.2.1–1.—*Potential Chemical Accident Scenarios – No Action*

Accident	Source Term or Hazard
Materials spill	400 L nitric acid solution (70%) 210 L acetone
Mercury release from ignitrons	9.8 g mercury
Aircraft crash	0.072 L mercury (980 g)
Earthquake	0.016 g beryllium 0.005 g uranium

Source: LLNL 2003d.
g = gram; L = liter.

Materials Spill

Solvents would be used for miscellaneous cleaning activities throughout the laser and target area and the optics assembly building; acidic and caustic solutions would also be used for various decontamination operations in the decontamination area of the Diagnostics Building. An anticipated scenario would be a spill of solvent or decontamination solution onto the ground outside the facility, possibly caused by a forklift during handling or movement.

The chemicals evaluated were selected on the basis of amount of material at risk, exposure criteria, and volatility. That is, chemicals without inventory thresholds that would be present in relatively small quantities, with low volatility, and those with relatively high exposure criteria were not considered further. Many of the solvents and decontamination chemicals potentially used at the NIF could be eliminated from further analysis on this basis (LLNL 2003d). In the end, one solvent (acetone) and one decontamination material (nitric acid) were selected to determine potential consequences.

Source Terms

The material from the spill was assumed to form a puddle on the ground that was subsequently allowed to evaporate. No mitigation was assumed. A minimum puddle depth of 1 centimeter was assumed, and the ambient temperature was assumed to be 95 degrees Fahrenheit (°F). The evaporated material would be dispersed to the environment. Based on the quantity of material available to spill, material properties, and hazard level, the most severe spill could be determined. This spill would bound the other spill scenarios.

Mercury Release from Ignitrons

Electrical equipment in the NIF could contain castor oil in the capacitors, mercury in the preamplifier module (PAM) power conditioning units (PCUs), or ethylene glycol, a PAM coolant. Mercury is significantly more hazardous than the other materials. Therefore, a scenario involving mercury has been selected.

PCUs would support the PAMs located in the laser bays. There would be 48 PCUs. Each PCU would have four ignitron switches, and each ignitron switch would contain 0.018 liter (245 grams) of mercury. A scenario involving a single PCU (four switches) has been postulated to bound the mercury release from the facility. The initiator for this scenario would be an explosive failure of an ignitron switch.

Source Terms

The explosive release would be expected to create a spray of liquid droplets and a small quantity of vapor under this bounding scenario. Though the PCUs would be enclosed in a 6-millimeter-thick steel box, the explosion would produce enough energy to cause the failure of this enclosure. The liquid droplets would deposit in the immediate vicinity of the failed switch and form a puddle, while the vapor would remain airborne. No mitigation was assumed. To evaluate the impact of this event, two source terms were estimated:

- The airborne mercury was estimated using a release fraction of 0.01, based on DOE-STD-1027; this corresponds to a total of 9.8 grams of airborne mercury.
- The puddle from the four failed PCU switches in one PCU would consist of approximately 0.072 liter (0.98 kilograms) of mercury. Evaporation of the mercury was determined for a puddle depth of 5 millimeters, at an ambient temperature of 68°F. The vapor would then be released to the environment through the laser bay HVAC discharge point.

Aircraft Crash

The probability of a light aircraft crash impacting the NIF laser and target area building would be a credible event; the frequency of occurrence would be approximately 1.6×10^{-4} per year. Specific areas of concern from a release of material standpoint would be the tritium-handling and processing/decontamination areas and the laser bays. If the aircraft crashed into other areas of the laser and target area building, there would be facility damage, but the accident would not result in the release of hazardous material.

The NIF target bay is constructed of thick, reinforced concrete. The primary purpose of this construction is radiological shielding; however, as an additional benefit, the construction also makes the facility essentially impervious to impact by light aircraft. Should an aircraft crash into the target bay, the chief hazard would be to the occupants of the aircraft and any onsite personnel in the way of falling plane wreckage and burning aviation fuel. The thickness of the reinforced concrete walls and roof are such that they would withstand the impact of a direct hit from a small aircraft. The switchyard is also constructed of reinforced concrete, a minimum of 0.61 meters thick. This area is also impervious to a light aircraft.

The roof of the laser bays and mechanical equipment area is steel deck with concrete fill, approximately 10 centimeters thick, and the exterior walls are metal siding. These areas would be vulnerable to damage from a small aircraft impact. There is a small possibility that an aircraft could impact PAM PCUs, different than the main PCUs located in the capacitor bays, and result in the release of mercury from the ignition switches. The PCUs would support the PAMs, which would be part of the preamplifier system that would provide laser energy gain to the low-level input pulse. The PCUs would be steel-framed boxes with 0.25-inch steel plate siding. The two laser bays would each house 24 PCUs, and each PCU would have four mercury-containing ignitron switches, for about 0.072 liters (0.98 kilograms) mercury total per PCU.

Only a small part of each laser bay's walls are actually exterior walls. Most of the laser bay walls are interior walls, adjoining the capacitor bays. Capacitor bays 1 and 4 would act as buffers between most of the laser bays and the exterior. A small aircraft crashing into an outer capacitor bay would not be expected to reach a laser bay. For an aircraft to reach a PAM PCU, a crash would have to occur either through the section of exposed laser bay wall (~150 feet for each laser bay) or through the laser bay roof. Penetration through the sidewalls of the laser bays and impacting a PAM would be extremely unlikely for a combination of reasons. First, the direction of the penetrating aircraft would have to be perpendicular to the normal flight path taken by aircraft in this area on approach to the Livermore Airport. Second, in addition to the direct protection the external capacitor bays would provide for the laser bay walls; they protrude and also would "shadow" or hide the exposed portion of the laser bay walls, considering the normal direction of travel of the aircraft, further reducing the available aircraft impact angle. Last, the 1.6×10^{-4} per year accident frequency pertains to the entire Laser and Target Area Building area. When the susceptible area (surface area of all 48 PCUs) is ratioed to the Laser and Target Area Building area, the accident probability is substantially reduced.

The roof of the laser bay would not provide much protection against a crashing airplane, but many obstacles would still stand between the plane and a PCU. Just below the roof is a layer of steel frames in the vertical, horizontal, and transverse directions. This layer would shear off the main body of the light aircraft and the fuel-filled wings. Because most of the mass of the light airplane is associated with the engine, it is this component of the plane that would cause the most damage. The engine would then have to pass through a series of barriers, including the beam transport system and a laser structural support system, comprising steel piping, steel reinforced concrete members, structural steel members, and concrete-steel composite members, before reaching a PCU. The aircraft engine must then penetrate the 0.25-inch steel panels of the PCU before damaging the set of ignitron switches. Consequently, a PCU located within a laser bay would not be affected by an aircraft crash, as these barriers would provide substantial protection.

Source Term

In the event such a remote incident would occur, only one PCU containing four switches, (0.072 liter or 0.98 kilograms of mercury, would be damaged. As there would be separation between the fuel in the wings and the aircraft engine upon impact with the roof, the spilled mercury would not be involved in a fire. The temperature of the mercury pool would be approximately 90 degrees centigrade (^{o}C), to account for possible heat transfer from warm engine parts. This scenario would then result in the evaporation of spilled mercury.

Particulate Release (Earthquake)

Several accident scenarios could result in the release of material in particulate form. They would be a waste drumfire, a target chamber vacuum window failure, and a beyond-design-basis earthquake.

The beyond-design-basis earthquake would be identical to the one described in the radiological release, Section M.5.5.1. The airborne release fraction for this scenario would be 1×10^{-3} and the respirable fraction would be 1. The airborne release fraction is defined as the ratio of the airborne material to the material at risk, and the respirable fraction is defined as the fraction of airborne material that is in the respirable range, meaning the aerodynamic equivalent diameter is less than 10 microns. This scenario would be used as a bounding case to estimate the amount of material in particulate form that would be released to the environment. A waste drum fire and a target vacuum window failure would be bounded by the earthquake scenario because the source terms and associated release fractions would be bounded by the earthquake.

An airborne release fraction of 10^{-3} can be applied to the material in particulate form. This gives the quantity of material that would become airborne, as summarized in Table M.5.6.2.1–1. No mitigation was assumed.

M.5.6.2.2 *Proposed Action*

No new accident scenarios would be created as a result of the Proposed Action. However, the source term for the particulate release scenario would change. Several accident scenarios could result in the release of material in the particulate form. They would be a waste drum fire, a target chamber vacuum window failure, and a beyond-design-basis earthquake. Table M.5.6.2.2–1 lists the source terms for the chemical accident scenarios.

TABLE M.5.6.2.2–1.—*Potential Chemical Accident Scenarios – Proposed Action*

Accident	Source Term or Hazard
Materials spill	400 L nitric acid solution (70%) 210 L acetone
Mercury release from ignitrons	9.8 g mercury
Aircraft crash	0.072 L mercury (980 g)
Earthquake	0.02 g beryllium 0.1 g uranium

Source: LLNL 2003d.
g = gram; L = liter.

The beyond-design -basis earthquake would be identical to the one described in the radiological release section. This scenario would be used as a bounding case to estimate the amount of material in particulate form released to the environment. The waste drum scenario and vacuum window failure scenario would be bounded by the earthquake scenario because the associated release fractions would be equal to or less than the associated release fractions for the earthquake. The particulate materials that would be released in this accident scenario would be lithium hydride, beryllium, uranium, and thorium. Because of the low radiological effects of uranium and thorium, they were also examined from a toxicological standpoint. The accident consequences for these materials are listed in Table M.5.6.2.2–2, for median meteorological conditions, and Table M.5.6.2.2–3, for unfavorable meteorological conditions.

TABLE M.5.6.2.2–2.—*National Ignition Facility Chemical Accident Consequences (Median Meteorology)*

		Noninvolved Worker		Site Boundary		
ERPG-2[a] Concentration (ppm)	**ERPG-3[a] Concentration (ppm)**	**Average Predicted Concentration (ppm)**	**Fraction of ERPG-2**	**Average Predicted Concentration (ppm)**	**Fraction of ERPG-2**	**ERPG-2 Distance (meters)**
Release of nitric acid solution						
6	78	199	33.2	17.6	2.93	604
Release of Acetone						
8,500	8,500	279	0.033	279	0.033	11
Mercury release from ignitrons						
0.25	0.5	0.0153	0.0612	0.0098	0.0392	23
Aircraft crash release of mercury						
0.25	0.5	0	0	0	0	< 10
Earthquake release of lithium hydride[b]						
0.31	1.56	0	0	0	0	< 10
Earthquake release of beryllium[b]						
0.068	0.27	0	0	0	0	< 10
Earthquake release of thorium[b]						
5.27	26.37	0	0	0	0	< 10
Earthquake release of uranium[b]						
0.103	1.03	0	0	0	0	< 10

Source: LLNL 2003d.
[a] ERPG=Emergency Response Planning Guideline.
[b] Smaller amounts used for No Action and Reduced Action Alternatives.
ppm = parts per million.

TABLE M.5.6.2.2–3.—*National Ignition Facility Chemical Accident Consequences (Unfavorable Meteorology)*

		Noninvolved Worker		Site Boundary		
ERPG-2[a] Concentration (ppm)	**ERPG-3[a] Concentration (ppm)**	**Average Predicted Concentration (ppm)**	**Fraction of ERPG-2**	**Average Predicted Concentration (ppm)**	**Fraction of ERPG-2**	**ERPG-2 Distance (meters)**
Release of nitric acid solution						
6	78	394	65.7	31.8	5.3	1,100
Release of acetone						
8,500	8,500	552	0.065	552	0.065	30
Mercury release from ignitrons						
0.25	0.5	0.25	1.0	0.164	0.66	100
Aircraft crash release of mercury						
0.25	0.5	0	0	0	0	11
Earthquake release of lithium hydride[b]						
0.31	1.56	0.1076	0.35	0	0	58
Earthquake release of beryllium[b]						
0.068	0.27	0	0	0	0	44
5.27	26.37	0.00128	2.43×10^{-4}	0	0	< 10
Earthquake release of uranium[b]						
0.103	1.03	0.00262	0.025	0	0	16

Source: LLNL 2003d.
[a] ERPG=Emergency Response Planning Guideline.
[b] Smaller amounts used for No Action and Reduced Action Alternatives.
ppm = parts per million.

M.5.6.3 *Transportation Accident Scenarios*

Under the No Action Alternative, Proposed Action, and Reduced Operation Alternative, radioactive materials would be shipped to LLNL from Los Alamos National Laboratory, as depicted in Table M.5.6.3-1. For a transportation shipment to undergo an accident in which radioactive materials would be released and expose members of the public, a high-impact accident with fire (a Category 8 accident as described by NRC (1977a), would have to occur. Of the four materials being transported, an accident involving plutonium would result in the greatest consequences, 11 person-rem with 6×10^{-3} LCFs. Under the Proposed Action, the probability of such an accident would be 3.5×10^{-11} per year, which would not be credible. Lesser accidents could injure drivers and members of the public, but would not result in release of radioactivity.

Under the No Action and Reduced Operation Alternatives, a tritium accident would result in the greatest impact. The result of a tritium accident would be 0.4 person-rem and 2×10^{-4} LCFs. The probabilities of such an accident would be 5.2×10^{-11} per year under the No Action Alternative and 3.5×10^{-11} per year under the Reduced Operation Alternative.

TABLE M.5.6.3–1.—*Annual Radiological Shipments under the No Action Alternative, Proposed Action, and Reduced Operation Alternative*

	No Action	Proposed Action	Reduced Operation
Plutonium	No shipments	10 shipments of 6 grams each	No shipments
Highly enriched uranium	No shipments	10 shipments of 3 grams each	No shipments
Depleted uranium	5 shipments of 0.2 grams each	10 shipments of 5 grams each	3 shipments of 0.2 grams each
Tritium	15 shipments of 100 curies each	15 shipments of 100 curies each	10 shipments of 100 curies each

Source: LLNL 2003d.

M.5.6.4 *Laser Exposure Accident*

The NIF laser could present a variety of hazards to both personnel operating the laser and others through exposure to direct or reflected beams. Under all alternatives, the risk of a laser accident would be similar. This would be most likely to occur during maintenance and could result in permanent disabling injuries to the eyes or severe burns if a worker were exposed. The likelihood of such an accident is considered to be a low frequency potential due to the numerous preventive features including enclosed beams, physical barriers, shutters, interlocks on the laser system, run/safety switches, visible and audible alarms, protective eye equipment, access control, pre-shot sequence, physical sweep of the laser area, personnel accountability, operations procedures, and training.

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